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MICROBIOLOGY.—*A microbiologist digs in the soil.*[1]

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PROLOGUE

For his last official appearance, custom has awarded this platform to each president of the Washington Academy of Sciences, without restriction in his choice of topic. For one night he can choose the title of his address and expand it without consulting with the Meetings Committee. Since he usually expects to continue living in this community, he is under prudential obligation to broaden his message to reach members of the Academy who care little for the specific field which he may have cultivated for half a lifetime.

His first embarrassment is the search for material which will satisfy this requirement. You will pardon me if I analyze this dilemma in a somewhat personal way. I have been a biologist for about sixty years; my father set me to trapping ground squirrels when I was six. Some of the experience of that first ecological assignment will appear in what is said here.

If you are to trap a squirrel, first you must find the squirrel's hole. Human philosophy will fail you. A squirrel selected the place to dig—only the squirrel knew why. How about a scientist! Here the safest course is to *"tell one"* on myself.

Many years ago, a trustee of the institution in which I was working brought a friend into my laboratory and said, "Tell us about your work." I knew that man's history—he had built success in life for twenty years around milking cows from 4 to 8 every morning and from 4 to 8 at night. I spent an hour discussing my project and showing the results attained. I thought I had done it rather well. Without a word or look at me, he turned to his guest and said, I'd hate to "earn my living as this fellow does." They went out.

Let us go back to our squirrel. Like the scientist, he is industrious. He piles up dirt about his hole as the scientist does monographs. But

[1] Address of the retiring president of the Washington Academy of Sciences, delivered February 17, 1938. Received February 18, 1938.

for the most part he is out of sight down his hole. No doubt he does a good job—down the hole. But down there his vision is limited by the crooks in his burrow. Now and then he ventures out, mounts his little pile and utters the chatter of his species. Equally the scientist appears before the Academy and when the brickbats begin to fly, dives back into his burrow whence a noxious flow of polysyllabic, technical jargon discourages all who seek to pursue.

I am not condemning the squirrel type of scientist. Sometimes a man is inspired to go off by himself and break into new ground. Again, it is either physically impossible to fit new ideas into existing systems, or, necessary to leave the integration of results to a coming generation. But it is always worth while to halt excavation operations until one has defined the real reason for digging.

Do not misunderstand me—I am quite sure that many a man can serve his generation best by selecting a limited field in which he digs deep and disregards his fellows—provided he definitely continues to dig and to monograph, but refrains from deciding all of the weighty problems of the world from data acquired—down his hole. I equally well know that the man who really digs deep, like the squirrel, comes upon roots of many kinds which lead in many directions so that a lifetime in what appears to be a very narrow hole, may develop contacts with the "ends of the earth." Nevertheless, for most of us it remains better that we confine ourselves to our monographs and refrain from settling all of the affairs of earth and heaven by what we find down our holes.

Thus I come to my subject.

A MICROBIOLOGIST DIGS IN THE SOIL

If a microbiologist who digs in the soil is to find excuse for discussing a series of questions of interest to those who care little for the description of microbes and microbial activities, it must be in the borderline of his field—not in its purely technical aspects. The broad significance of his work will appeal to some, whereas his points of contact with men and movements outside, as viewed from his special angle, will interest others. The details of his laboratory and field operations only reach those critically familiar with both soil technology and microbiological procedures.

However dead the earth may look and be considered in our thoughtless moments, the experience of man far back beyond his written records has led him to associate trouble capable of multiplying itself as coming from dirt. Bacillus tetanus, amoebic dysentery, thermo-

philic spoilage, actinomycosis and botulism, are new terms, but the need of freedom from earth in wounds, in food, and in clothing is no recent discovery. The demonstration that soil, instead of being all dead, harbors millions of organisms, releases that flight of imagination which pictures the soil as a sort of Lilliputian zoo in which some magic hand has eliminated all barriers and set free every grade of minute but rapacious monster to go roaring after the next lesser grade as its lawful prey. Thus the soil is pictured to us in terms that lead us to ask what manner of thing it is.

The mass is firm. We walk upon it. We dump into it the waste, the worthless and the unwanted. Somehow all disappear. We look at it and thoughtlessly think of it as the product of the disintegrating power of cold, heat, rain, snow and all the other lifeless forces of the earth, yet the late Professor Marbut in one of his lectures said, "However fundamental climatic forces may be, they are destructive, not constructive." In their effect upon the surface layer of the earth, "They stop with gravel, sand, silt and clay." No one familiar with the waste places of earth fails to recognize in these words the desert. Then Marbut added, "Climate produces parent material, life makes it soil." Yet nowhere does the living micropopulation constitute more than a minute fraction of the soil mass.

The Soil Profile:—A vertical section of the soil is called a soil profile and its more or less apparent layers are designated horizons. The orthodox soil sampler interprets soil as earthy material hence brushes away all of the accumulated waste such as dead leaves, stems, and bits of animal matter which he calls the A_0 horizon. His soil begins only when he reaches amorphous material. From this, after his sample is taken, he discards all visible masses—recognizable as vegetable or animal in origin, and minerals larger than sand. The more progressive soil microbiologists, however, can not accept a distinction between pieces of root, for example, easily picked out, and the multitude of bits of living or dead roots which escape detection hence remain in the sample. They therefore have adopted this no man's land (horizon A_0) as microbiologically interesting, important and logically part of their territory.

Below this layer of organic matter we see a surface layer (A) the soil proper (solum) containing the black or brown organic substance known as humus, a second layer (the subsoil, B) partly colored or streaked with humus, and a third layer (C) composed of mineral soil materials. The organic factor in the upper layers constructively distinguishes them from the soil materials—mineral in character below.

The transition from one horizon to the other may be gradual or abrupt. On the basis of the structure and chemical composition of these horizons, the Soil Survey has listed and described something like 1,700 varieties or types of "virgin" soil in the United States alone, and a myriad more of types in other parts of the world. We are bewildered by the endless diversity in description of superficial form and structural arrangement; we are confused by formidable geological theories and impressive chemical diagrams. Regardless of these differences, some of us find evidences everywhere of fundamental homogeneities. Soil forming processes are great levellers. Universally distributed groups of organisms and universal organic processes are involved in the decomposition of plant and animal remains and in the subsequent transformation of the by-products of this decomposition into food for green plants. These processes follow lines which are much the same throughout the world, hence the heterogeneity of the picture is in detail—the really striking thing is, that a significant homogeneity can be traced through so complex a mineral substratum grown through and through by multitudes of individual organisms belonging to diverse groups.

Constructively below ground, the microbiologist is academically free. He can report his exact findings without risk of controversy outside the soil group. Within that group, controversy is the rule, not the exception. Geologist, chemist, physicist, botanist and agronomist —each claims a proprietary interest in the soil. Each looks at it from a different angle. Each feels abundantly able to defend his claims.

Academic freedom among scholars is limited by discretion. Within the narrow field in which a man has earned the right to speak, he is commonly heard with respect. Outside that area he is just another commentator from second-hand data with no special right to consideration. If he generalizes too broadly from the findings of his narrow field, he is promptly challenged by some one equally learned and equally sure that he has gleaned the truth, but a different truth from another line of investigation. Unfortunately the temptation to let our tongues run at large is always present.

I heard a man once report some very stimulating experiments with (shall I say?) geese—and apply the results to support his own view of a controversy about man involving not only physical but intellectual and social values. Another paused in a purely earthly discussion to regret that the Christian's idea of God is "not yet extinct." Such incidents are legion; one can stand in awe before him who is ready to die for a conviction but in some cases he would be tempted

to applaud the executioner. In our field there does not seem to be any ground to cavil at the oath of allegiance and it is hard to see any definite relation of our data to meditative philosophical systems.

Generalizing from the particular is an ancient sin. Experiments with soil are expensive, laborious and time consuming. One man uses undescribed earthy material in which he plants millet, a second plants tomatoes, a third rye, and all summarize by discussing the reactions of "plants in soil." The microbiologist is not free from guilt—he weighs out 50 grams of "soil" adds 2 grams of this or that, incubates, analyzes and decides that microbial activity in "soil" is measurable in "x" milligrams or "y" parts per million of "A". The complexity of the micropopulation, further complicated by the difficultly measurable environmental factors, warns us that the most explicit statement of materials and procedures, will add greatly to the usefulness of our data. We are always thankful to the man who tells us exactly what he has done, how he did it and who details his results in sharply defined terms. We are also interested in the way he believes those results to fit into some philosophic whole to round out our knowledge of a particular field. But if he chooses to break over into the field of abstract meditation, we have only one request—that he shall not spoil the value of his scientific contribution by confusing his meditations with his observations.

Having attended a great many meetings of "learned" societies, having published rather freely, having read bales of "proceedings," and having stood at the foot of several martyr monuments, I sometimes wonder how much philosophical turmoil and physical violence might have been avoided if men had always distinguished clearly between essentials of truth in their experience and weird meditation which had no basis in truth.

But let us get back to our soil population. One of the first questions raised is—how large is this micropopulation? Some figures may be cited. The Rothamsted group reports between 15 and 25 millions to the gram; Brown and his colleagues in Iowa consistently found 2 to 6 millions; Waksman in New Jersey got 30,000 to 8 or 9 millions; Conn in New York State reported 5 to 400 millions. Each claimed to have determined the total population; the methods used diverged widely. These figures are sufficient to show that numbers alone help little, even though determined in a punctiliously taken representative sample, composited and homogenized from a series of cores taken at specified distances with the sampling tube. If such determinations are correlated with the factors in that soil which determine its use-

fulness, then if those factors are subsequently altered, and the soil is reexamined by the same worker, we obtain useful contrasts. We conclude that such bacterial counting by any method rigidly standardized may establish a population level or partial population-level or density, characteristic of a particular type of soil in a particular condition. Marked rise or fall of that micropopulation from that level may be correlated with favorable or unfavorable cropping conditions. At best, we have not yet reached the point where we feel warranted in trying to use such bacterial counts for practical ends. The great volume of work done has given us a general concept of population levels, related but not very closely, to soil descriptions.

This micropopulation has been described as composed of "myriads of interlocking units" which make up a "microcosm." Counts of this population as already cited run from a few thousands to the gram in a very acid soil to some hundreds of millions or more under special conditions. Sir John Russell and his colleagues at Rothamsted conclude that "about 20,000,000 bacteria per gram of soil is now considered a fair average number." This figure is based upon the "plate count" of the bacteriological laboratory made from samples of a good grade of cropping soil. If we add to Russell's figure the remainder of the population—molds, yeasts, protozoa, algae, etc., many of which scarcely appear in the ordinary "colony count" of the culture laboratory—we might increase it perhaps 25 per cent. This would make 25,000,000 as an average total population figure for the type of sample used as a representative.

A few generalizations about these organisms may be worth giving. Dig into the soil and you find here and there a larger animal or more frequently, a burrow—but you see none of these millions. You might roll the whole 25 millions into a pellet and it would be as large as a very small grain of sand. It would take about 25,000 such pellets to make a cubic centimeter. Yet their activities are measurable in various ways. Tests show that carbon dioxide evolved by respiration of these organisms escapes constantly in measurable quantities from the surface of the soil. Daily and hourly counts show constantly changing numbers. There is activity as long as reaction, temperature, moisture and food supplies permit. Few of them are destroyed by summer's heat or winter's cold, by flood or by drought. Even after the laboratory sampler has air-dried his earth, thrown out every piece of so-called foreign matter which he could see, crushed it with a roller to powder, then run it through a 2 mm sieve—those bacteria are yet

there. Pour a little of that soil into a sterile container of fermentable material and in a few hours of incubation it becomes a seething mass of microorganisms.

Statistical Analysis:—The totals of population cited from different authorities vary sufficiently to require further discussion. If we scrutinize the figures for each tubeful of earth composited in making up the sample for determining these population totals, we find divergences in successive sampling from the same area so great as to trouble those bacteriologists to whom mathematical expressions of this kind are presumed either to have an exact meaning or, in their variation to hide something discernible by proper analysis. From such studies they have published page after page of graphs purporting to synthesize in a statistical way, totals of bacterial counts varying (let us say) from 13 to 23 millions and searching for a mathematical meaning in such differences from samples taken out of a single field. Physical, chemical and general biological data in these samples were ignored. Despite their efforts to obtain homogeneity, those long familiar with the hundreds of millions or even billions of bacteria per gram associated with actively rotting substances elsewhere, would be surprised if spaced samples from such a heterogeneous mass as soil gave totals varying less than 25, 50 or even 100%. Physical examination of the soil profile reveals so great variety of visible components as to forbid anticipation of close correspondence in bacterial populations in such samples even though the operator may throw out all visible pieces of rotten vegetation, living earthworm or dead cat, that happen to be caught by his sample tube. One wise old soil chemist expressed the opinion that he lost essential and valuable information if the laboratory helper put the sample through the homogenizing process before he saw it.

No one doubts the important service of statistics in fields where hundreds and thousands of items of reasonably nearly the same kind must be brought together for a specific purpose. In fields such as soil bacteriology in which physical limitations reduce the samples which one group can examine, to numbers readily grasped as individual figures in a table, the significance of the actual figures and their relation directly to characters within each sample, commonly far surpass in importance any generalization by statistical analysis of the group of samples. The question is not, shall statistics be applied, but where shall they be applied that they may contribute to, rather than obscure our search for truth.

If future studies of total soil populations are to yield important

information, the samples taken must be fully integrated with all we know about the soil.

This changed attitude is represented in recent Canadian papers by Timonin and Gray in which series of samples were taken from well identified soil types. Temperature, water content, reaction, and organic matter were measured and recorded against the bacterial counts of every sample. The results point the way for future studies in this field.

If we accept the fact of a large micropopulation, we are faced with problems of analysis and interpretation. What do we know of these microbes and how can we use them? Intelligent control of the organisms encountered in farm operations, with the exception of a single group, stops at the surface of the ground. Nature has furnished the farmer with his soil-type and with his climate. The farmer knows how to handle such crop-associates as weeds, nurse-crops, or cover crops. At its entrance into the soil, his crop-plant passes into an environment which is unknown to the farmer, and almost unknown to the scientist. There the crop-plant must compete with a multitude of species of molds, bacteria and protozoa as well as more complex animal and plant forms. Of these we know something about certain species which are destructive parasites; we have actually learned to utilize the legume nodule bacteria, but the multitudinous remainder continue to be a task for the future. We have at present no consistent picture of what goes on—below ground.

Our twenty-five millions of microorganisms to the gram present a whole series of other problems that lead in different directions. To the systematist of a generation just past, they presented a new and great floristic field which yielded long lists of species new to science, and ecological situations of the utmost interest, because related in so many ways to human welfare.

American attempts at classifying soil organisms began scarcely 40 years ago. Some of those who set the original landmarks are still at work—notably Chester and Lipman. None of us are real pioneers. Decomposition of organic matter as a phenomenon had been common knowledge of mankind for ages. The use of manures for crop growing was already ancient in Bible times. Legumes as soil improvers were known to the Romans. The outlines of the nitrogen cycle had been already drawn and values measured step by step by chemists. Even sterilization of media goes back to Pasteur who was not interested in soil. We may as well confess that biologists did not start investigations in soil bacteriology; they were dragged in by the demand that the

organisms whose presence was predicated by facts well established, be identified and studied. To satisfy this demand, men entered bacteriology from two directions. The botanists brought morphology bolstered by a smattering of chemistry into the study of microscopic species. The chemists brought quantitative analytical methods but little morphology and too often, no desire for any.

The earlier studies were largely morphological and attributable to such outstanding figures as DeBary, Brefeld and Ferdinand Cohn among the botanists. The microbiological literature of that period (1850 to 1870) was filled with descriptions of polymorphism in the fungi. Men who knew that they could plant an acorn or a potato, and follow its whole life history, thought a mold or a bacterium was different. In the early days of the culture laboratory men started with what they thought was one species and ended with a menagerie. They gravely described the whole aggregation as different manifestations of a single form of life—the dissertations of that period are interesting. Be it known we still receive cultures—supposed to be particular molds, in which two or three fungi, a half dozen bacterial strains, an occasional mite and a few protozoa may be found to complicate identification.

The idea of pure culture developed slowly; some have not caught it even now. A microorganism often presents strikingly different appearances upon different culture media. What appears to be strictly a green Aspergillus on a pair of moldy shoes, becomes a dense layer of yellow to orange fruit bodies (perithecia) upon 40% sucrose agar. Is it any wonder that polymorphism caught the fancy of whole groups of men between 1850 and 1880? Similar contrasts are easily cited for soil bacteria. With improvement of apparatus, it became easy to separate species whose mixtures presented great difficulties to Brefeld.

In the swing away from polymorphism taxonomists accepted the idea that fundamentals of structure (what are fundamentals anyway?) could be assumed to be fixed species characters. Color, shape of units, size of units, aggregation into chains, plates or "packets" were selected as diagnostic. Although whole series of strains did not fit into the preconceived scheme of things, for the time they were discarded with a pretext for dismissal. The idea of dependably fixed but abstract species-characters developed, and remains today, an endemic infection in many strata of workers who deal with microorganisms.

The botanical bacteriologists had started with floristic studies. They made lists of microorganisms found in particular soil popula-

tions; they isolated and described new species. They carried over into bacterial characterization, detailed description of the color, size and shape of cells, of cilia, of flagella, of spores, of thickness of cell walls, of aggregations of units into filaments or masses. Every variation from type description was given a new name. In accord with botanical usages, the substratum in which the species was first found was designated as habitat, and the geographical region was entered in the record as locality. The arbitrary conventionalism that the substratum and place of first discovery typifies the species, has made constant trouble in subsequent studies of higher plants: when applied to microorganisms it produces chaos.

To the early taxonomist the description of a microorganism was a simple process. Nature was assumed to be made up of units which as collected represented species. It was assumed that if the original specimen were described and preserved, succeeding workers had but to fit their findings to existing diagnostic literature and label their material accordingly.

From such activity, we inherit long lists of names for species whose type-habitat is *soil*. Believing the numbers of species few and readily separated by brief morphological diagnoses the early describers made simple task of it. Only a few of their species are safely identifiable today and still less of them are correlated with their distribution and function in nature.

Nomenclature and classification of organisms great and small dominated biology for many years. Perhaps it has been partially brushed aside on account of sins of scholarship, but no one has yet suggested a practical method of conveying information useful to his fellows, about a particular organism, without some kind of name and grouping definite enough to identify it to his reader or hearer. The vast literature of biology opens only to him who has for his organism the name under which that organism has been discussed by his predecessors. How can we understand each other if a microorganism appears in the soil under one name, and in medical bacteriology under another, or perhaps two more? This is no impossible conception. Examples are easily cited. Every organism great or small, eventually comes upon or into the soil. There are probably 100,000 kinds of fungi and nobody knows how many bacteria. Finding an organism in the soil may mean much or little—it may open vistas in soil biology; it may prove to be an inconspicuous saprophyte; or it may be a pathogen well-known to medical bacteriologists, if proper steps are taken to identify it.

Identification of species is more important today than ever before. Long, tedious and expensive investigations of incorrectly identified organisms have been repeatedly published to plague us indefinitely with citations of activity which no one can verify and no one can refute. Whatever excuse may be offered for the past, there should be no place in publication today for elaborate discussion of unidentifiable material.

One looks in vain through Bergey's Manual for recognition of many species which were long ago named and described for activities in the soil. Although the old barriers between groups of bacteriologists have partially broken down, there are still men working in medical laboratories, or dairy laboratories, who forget that dirt does get into almost everything hence lists of soil organisms should be searched before new species are described from other sources. Yes, and there are soil men whose eyes rarely see anything but dirt and to whom medical bacteriology is not only a foreign field, but one upon which they rarely even look—over the fence. We can no longer shirk recognition that any bacterium of any type-habitat, may come up to plague us in our soil studies. Special brands of biologists can hardly hope to live by themselves and do work in peace. Professor Bailey once made the remark that a particular scientist had relieved the situation by resigning, adding, "We never had but the one man about here who tried to put a high fence around his field and keep the rest of us out. We all took special delight in throwing our 'dead cats' over that fence."

The chemical bacteriologists likewise developed two lines of attack. Some tested for biological activities in mass. Thousands of samples of soil were taken by standardized procedure, analyzed, incubated and re-analyzed; I saw 5,000 flasks (Göttingen, 1905) incubating at one time for nitrification testing in a great laboratory; such results were aggregated into generalizations about soil fertility but the agents active were assumed, not known, and unfortunately sometimes they were not there. Broad differences in nitrification within great soil groups were readily established: when applied to particular cropping areas, the results were disappointing.

Such tests continue in use today but for restricted purposes or special intensive comparisons only; standardization in soil testing in the laboratory loses sight of so many biological factors operating in the field that the results can only apply within narrow limits to the solution of particular cropping problems. However suggestive the theoretic considerations may have been, very few of the tables covering thou-

sands upon thousands of such determinations have any interest today.

The procedures of bacteriology have automatically tended to center activity upon the laboratory so completely as to give color to the charge that a pint of soil sent in by a correspondent can keep a whole group working for several years without feeling the necessity of going back to examine the field. The sum of abstract human knowledge perhaps grows thereby but perspective in presenting the specific information as a part of an integrated whole, is wanting.

In such studies, the single organism, the species and even whole groups were lost to consideration. Whole populations were dealt with in mass. The existence of discordant elements in such populations showed here and there in the results obtained. The biochemist had perforce to turn to the single species in pure culture to analyze his troubles. Here again there is a long story but only time for a few glimpses of its development.

As an example, Beijerinck's *Azotobacter* which fixes atomospheric nitrogen very accommodatingly in the laboratory, caught the imagination of soil men over the whole world. Publications by hundreds deal with *A. chroococcum* in the laboratory, or, with merely finding it in the field. Imaginative calculators have estimated its service to agriculture as an annual contribution in fabulous figures, but when what we actually know about *A. chroococcum* in the field is put to the crucial test that units of particular bacterial species must be present in countless millions if that species is to play a large part in soil processes, the probable significance of *Azotobacter* shrinks toward the mythical. No one has been able to find more than a few thousands to the gram anywhere and sometimes it is difficult to find at all. While hope still lingers that Beijerinck's organism may somehow and sometime be found to satisfy the fond dreams of its laboratory devotees, the iconoclasts have largely turned away in quest for some other agent to explain the nitrogen fixation known to occur.

Frequency of appearance in routine culture does not necessarily indicate significant responsibility for biochemical activity in the soil. *Aspergillus fumigatus* is world-wide in its distribution in the soil, but it is equally common in decaying vegetation and in and upon cereal grains; it is parasitic in the lungs of birds and sometimes even in man. It grows readily from near the freezing point to 45°C. Like most cosmopolitan organisms it is also omnivorous; it produces a wide variety of enzymes. In laboratory test one strain of it from the soil broke down cellulose so readily that its finder, not knowing the species, called it *Aspergillus cellulosae*. Nevertheless, there is little

evidence that this species produces in the soil sufficient masses of vegetative mycelium to be a real factor in the breakdown of plant remains. This is only one example: Soil mycology papers list whole series of species easily isolated, universally distributed, but on account of their limitation in mass development, only capable of being minor contributors to the aggregate of biochemical changes in the soil. Nevertheless we have extensive researches upon the biochemical activities of many of these species.

As an example in sharp contrast, matted mycelium was easily seen throughout the top inch of the mineral soil in several acres of a wooded area in southern Virginia. Conspicuous fruit bodies connected directly with the strands in this top soil identified the organism as a species of *Clavaria*, yet no one has ever reported *Clavaria* in laboratory cultures from soil nor has anyone tested this Hymenomycete for biochemical significance. The mushrooms, puffballs and related forms are constant members of the soil population and form great masses of vegetative mycelium but only a few of them fruit readily in laboratory culture. Identification of their mycelia when they do appear is commonly impossible. Aside from the cultivated mushroom, we know therefore exceedingly little of the vegetative activity of the soil inhabiting members of this whole group with its thousands of species, although there is constant evidence of their presence in mass in the field. A new line of attack will be necessary if we are to evaluate their contribution to soil changes.

Search for organisms capable of special activity has taken many forms. One of the commonest has been the preparation of the so-called "enrichment" media. For this purpose, culture solutions prepared to contain approximately the necessary elements for growth have been used to test for species capable of attacking wide ranges of organic and inorganic substances. Cellulose fermenting forms have been studied extensively. Iron bacteria, sulphur bacteria and selenium fungi have been given recent and rather conspicuous attention. Once in the laboratory few of these organisms have been followed back to the soil to prove their significance or establish their exact relationship to soil processes.

The classic nitrification work of Winogradsky, and the arsenic studies of Gosio, go back to the 1890's. A few years ago we had occasion to repeat arsenic work of Gosio and found other species in the soil capable of disclosing the presence of arsenic by volatilizing it when present even in very small quantities. We were promptly called upon to produce fungi capable of volatilizing 1,500 pounds of lead-arsenate

to the acre, that we might rid certain areas of this excess. Even if it had been possible to produce a mold population capable of this activity within a reasonable time, man and beast would have needed to move from that neighborhood during the process to escape the odors evolved.

To read some of this literature one would expect Gosio's mold to be a conspicuous example of a species with specialized relations to the environment, but in fact it (*Penicillium brevicaule* or *Scopulariopsis*) is a cosmopolitan saprophyte which is found in the soil everywhere; it produces ammonia in cheese cellars; it contaminates stored meat; it has been found abundantly upon poorly cured hay, and in a thousand other places. Its effect upon arsenicals does not seem to have any necessary connection with its growth and development in nature.

Whole series of studies of "named" species have been made in which no evidence of significant relation to soil problems is presented. Unless a species can be found capable of development in mass under actual soil conditions, the demonstration of such an activity *in vitro* merely raises the possibility of function somewhere in nature: it does not establish the importance of the species as a biochemical agent in the soil.

The history of this quantitative literature about single species is most interesting. The idea of specificity of activity had crept into microbiological literature far back in the 19th Century. Each organism was pictured to us as performing one function. The organic cycle became the original pattern for the factory assembly line. Decomposition was supposed to be accomplished step by step. The first agent performed one process then ceased. A second organism performed the next process and so on until the end. Recomposition was the same process reversed. The only difficulty about it is that it is not true. The agents of decomposition are a tremendously complex aggregation of competing units of many groups; some of them are capable of performing many functions although no species perhaps is able to complete the whole process. Such a thing as a succession of organisms exists perhaps in theory but under natural conditions these activities overlap so completely, and duplicating species are so numerous, that the old certainties of succession are gone. Nevertheless we find persistent faith in the traditions of our great authorities.

In the purely chemical scheme of things a microorganism became a special kind of reagent which was to be procured from a morphological systematist and which could be kept in a bottle with a name on it, and called upon at will to produce one definite measurable

effect under specific conditions. We are told that if a proper survey of these activities were made, the whole course of nature would be predictable. The biometrists would reduce biology to equations. The doctrine is defended as a legitimate part of a mechanistic philosophy. But we face the fact that the simplest of those complex biological processes as worked out in the laboratory, took the genius of a generation of chemists to unravel and constantly requires the intelligent skill of expert chemists to operate. The infinitely complex processes which we see undescribed would need omniscience to reduce to formulae and mechanism, and take both omniscience and omnipotence to operate. So far as the present situation appears, we have done little more than substitute a new batch of incomprehensible terms for the usages of the old time vitalist. We must welcome every determination and every observation which helps establish our control of new processes and our restatement of old problems, but the limitlessness of the fields opened up give little promise of completed knowledge thus far.

Obviously each step we have discussed tended to carry us farther and farther away from the soil: There are other soil problems to be considered.

Dependence on food supplies:—Many descriptions of great micropopulations report the organisms as growing in the soil but do not recognize the necessity of organic remains as food supply back of such aggregates. Even discussions of root rot fungi sometimes put forward the bald assumption that as vegetative mycelia they start from some point then spread blindly in all directions, attacking and killing roots of crop plants when encountered at any point on the advancing front. To meet this hypothetical picture, Miss Morrow and her co-workers in Texas excavated whole root systems of cotton plants and demonstrated that root rot fungi follow visible roots and pass to new plants where interlacing rootlets meet between the rows of host plants. Lines of infection are not due to "scout" mycelia hunting new victims but to contact transference. Fungi and bacteria in the soil follow food supply—they do not search blindly for it. Parasitism upon living roots, however important to the crop grower, accounts for little of the soil microbic activity.

The complex interlacing root systems represented by a sod are familiar. Dittmer computed that his rye plant specially grown in a box 12 by 12 by 22 inches for 4 months, produced a root system containing some 13 millions of units, totalling 387 miles in length. We may disregard these exact figures but they emphasize the complete-

ness of penetration of the soil by the roots of crop plants as ordinarily spaced in the field. If you cut a block from the forest floor, the mass is often held together with interlacing tree roots forming half its volume. At the end of a cropping season in a humid area, the whole surface soil is readily seen to be matted with roots of corn, wheat or cotton. Microorganisms are present along every millimeter of these root systems while living. The background is thus prepared for the development of immense numbers of bacteria when the surface growth is destroyed and the root systems die. Even in the unplowed land, root pruning both of trees and of herbaceous perennials furnishes a continuous supply of dead and dying plant material. Decomposition of annuals, becomes an explosive process involving the development of countless millions of bacteria. There is thus a continuity of food supply under soil conditions that provides for great micropopulations; there is microbial activity continuous but fluctuating widely with the abundance of food and the variation of climatic conditions.

Soil microbiologists have done something toward describing what we find in these tremendously complex aggregates of roots and microbes. In one single group they have gone farther and found that particular bacteria may be isolated by proper methods and inoculated or planted upon the seed or in the soil, to produce a known and desirable end. Nodules occur upon the roots of a long list of leguminous plants. By proper culture, we isolate the organisms, *Rhizobia*, from the nodules, propagate them in pure culture, and put them back in the soil or upon plants of the same kind, and render these plants effective and profitable crops in poor soils in which they grew feebly without these bacteria. This symbiotic relation makes possible the accumulation and fixation of nitrogen from the air—hence this whole group of leguminous plants becomes immensely valuable in our campaign for land improvement. The history of this achievement is told in a book by Fred and his colleagues, who cite their sources in 2,000 publications produced mostly within the last 50 years.

Repeated attempts to exercise such control with other crops and other bacteria have failed. Our people working in Texas have in the past two years, inoculated plants with particular organisms and appear to recover those organisms at will—but thus far attempts at practical applications have not succeeded. That field is open and scarcely explored today. There is every reason to believe that it has great possibilities.

This tale of mine might have been designated, confessions. It tells of failures, of futile ideas followed until the worker reached the

dilemma of the Experiment Station which was said to have "spent so much money on Dr. A's attempt to climb a tree that they did not dare let him come down." It recites the history of things partly done and abandoned. It lists unfinished tasks. But it also tells of visions of problems worth doing which are brought into bold relief by the work already done.

Bacteriology, as a branch of biology, is new. There are men in this room who can remember how the world hailed the pioneer discoveries of Robert Koch in the 1880's. It took twenty years more to bring the procedures of the bacteriological laboratory to a stage in which the worker could keep his vision partly on the ends to be obtained instead of solely upon the manipulations necessary to reach any results.

Microbiologically, "below ground" was outside the field of science a half century ago. Like the squirrel of our prologue, the worker had to feel his way. Is it any wonder that sometimes he got lost?

Twenty-five millions of organisms to the gram of soil! Bacteria, molds, actinomycetes, myxomycetes, algae, protozoa and more complex!—they fill a microbiological jungle in which friends and foes, saprophytes and parasites, symbionts and antagonists compete with each other and with crop plants for space and food. They are a challenge to our skill in culture, to our discrimination in interpretation and to our constructive imagination in devising means to control and direct these myriads to useful ends.

GEOLOGY.—*Prismatic jointing in Triassic diabase of Virginia.*[1] ROLAND V. WARD and JOSEPH K. ROBERTS, University of Virginia. (Communicated by ROLAND W. BROWN.)

Prismatic jointing in Triassic diabase of Virginia was first observed during the summer of 1929 when a quarry for road metal was opened in Fauquier County, approximately 4 miles northwest of Remington, near U. S. Highway 29. At the present time the quarry is in operation, and the enlarged dimensions have been sufficiently extensive to expose the jointing in fresh condition, which has enabled a more detailed investigation, especially in the mineral content of the diabase. The quarry is approximately 100 by 200 feet, and about 15 feet deep.

Diabase is widespread over the Triassic belts of Virginia, also over much of the Piedmont and Blue Ridge, and a portion of the Valley province. This rock occurs both as intrusives and extrusives in the Border conglomerate, Manassas sandstone, and Bull Run shales of

[1] Received February 3, 1938.

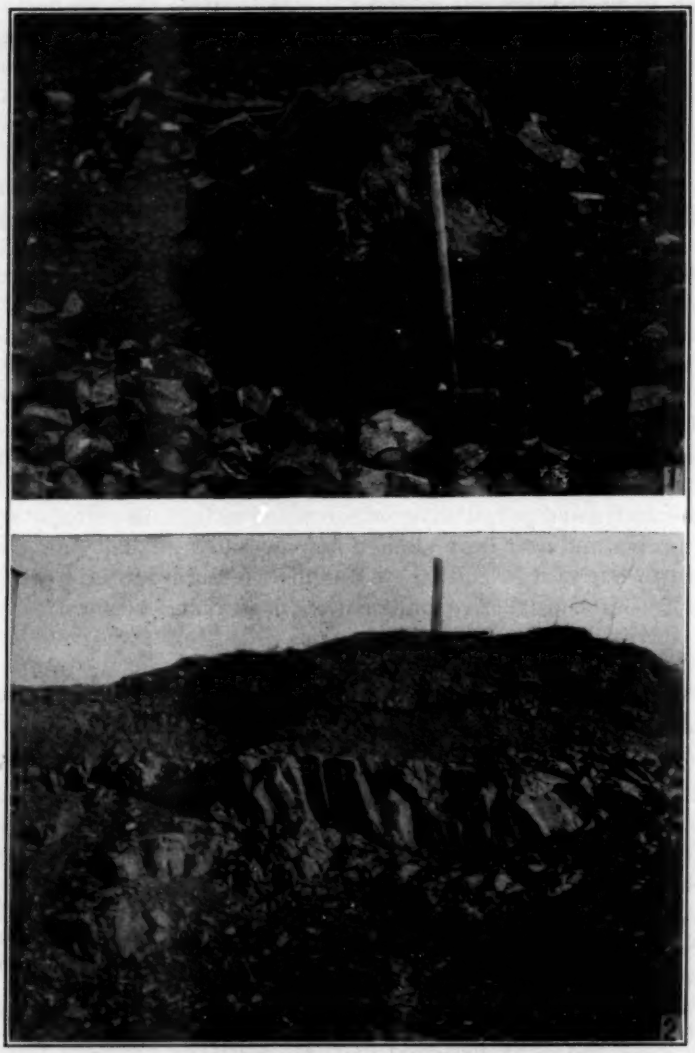

Fig. 1.—A block of diabase after blasting, showing prisms of diabase.
Fig. 2.—View of the prismatic diabase in place.

Upper Triassic age. In the above mentioned quarry the diabase occurs in the form of an extrusive sheet, and it has the apparent strike of N-70-E to N-80-E, and the prisms dip from 68° to 72° in a N-15-E direction. If the prisms were originally in a vertical position, their present position is to be accounted for by later movements. Of the twenty prisms measured, thirteen are pentagonal and seven hexagonal. None with three, four, or more than six sides were observed anywhere in the quarry. The sides of the prisms are generally smooth although a few are curved and irregular. Some taper to a slight extent. The usual transverse breaking into convex and concave surfaces was observed in only a few specimens. Width of the faces ranges from 3 to 10 inches. Only a very few prisms show any tendency toward equilateral faces as in the Giant's Causeway, the Devil's Tower, or the extrusive sheets of Idaho, Oregon, and Washington. The prisms fit tightly together in the fresher diabase, and even more compactly in the weathered rock.

The fresh diabase shows a dull, dark blue color but changes with the degree of weathering to a reddish brown. The fresh rock is hard and brittle, and maintains a remarkable uniformity in physical properties over the Triassic areas of Virginia. The most highly weathered phases of the diabase crumble easily, and form a characteristically red residual soil. The megascopic texture is fine grained to dense as observed in the quarry. On one side of the quarry the diabase is jointed, while on the other side it appears sheet-like. In the latter form the amygdaloidal structure occurs, and less frequently in the prismatic diabase. The amygdules vary from a fraction of a millimeter up to 30 millimeters. In practically all of the amygdules are found silica in the form of chalcedony, and subordinate amounts of quartz and calcite. There are white stringers of chalcedony, and calcite filling fissures whose length rarely exceeds 8 centimeters, and width 2 millimeters. No evidence of flow structure has been observed, even under the microscope. Amygdaloidal structure does not show in the weathered zone, which extends down about five feet.

Microscopically the prismatic diabase shows a typical ophitic texture, an intergrowth of lath-shaped feldspars and pyroxenes. These crystals are small, suggest a slower rate of cooling than would have occurred in the uppermost layers of an extrusive sheet, but compose a much finer texture than would have resulted from the cooling of an intrusive sheet of any considerable dimensions. This intergrowth shows a greater abundance of feldspar and a smaller proportion of pyroxene than much of the Triassic diabase of Piedmont Virginia,

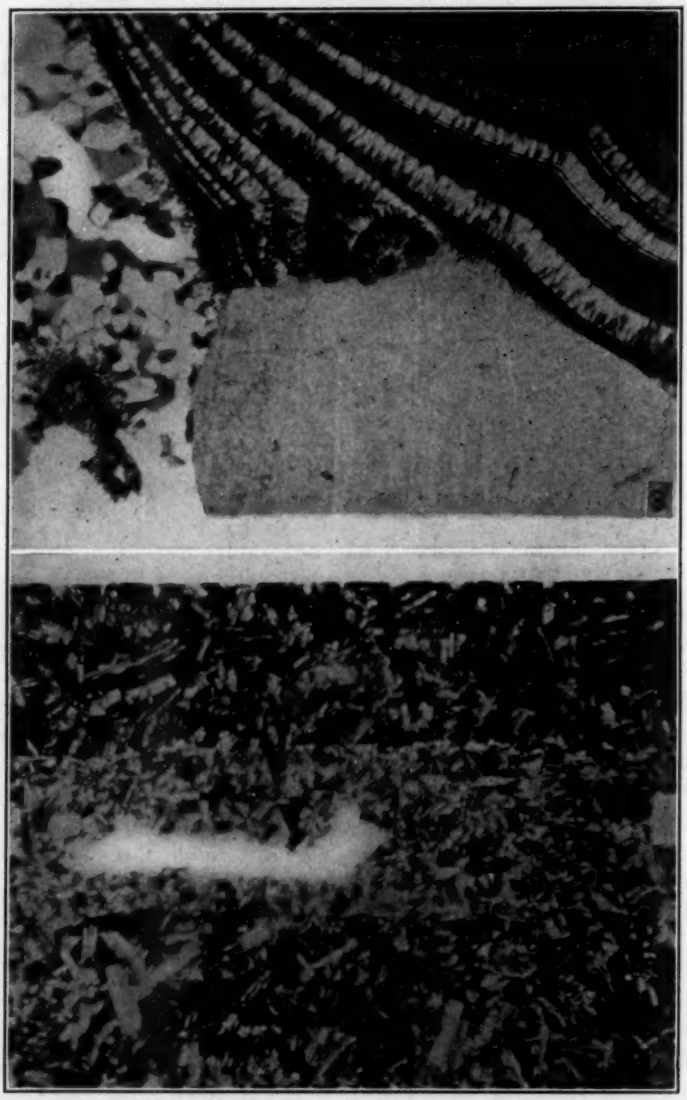

Fig. 3.—Photomicrograph showing banded chalcedony, a spherulite lying near a calcite crystal, and granular quartz. ×50. Fig. 4.—Photomicrograph of diabase showing a stringer of opalized silica with a long calcite crystal. ×50.

otherwise it differs in no way from that of the other diabase of dikes and stocks of the Triassic. The fabric is generally even but in places irregular. The texture of the prisms remains quite uniform in both vertical and horizontal directions.

The principal minerals are labradorite and augite. The labradorite shows twinning despite the variable degrees of weathering, which cause it to appear as corroded. The augite has apparently undergone more alteration than the labradorite. Some of it has altered to chlorite magnetite, and other undetermined oxides of iron. Certain pyroxene crystals too small to be identified with certainty are believed to be hypersthene.

The accessory minerals which occur in small and variable amounts are small anhedral grains of quartz scattered through the rock, occasional crystals of apatite, and ghost crystals of olivine. Small amounts of biotite were observed in some sections. Secondary minerals comprise subordinate proportions of chlorite, calcite, sericite, magnetite, other iron oxides, and chalcedony. Stringers are filled with chalcedony, which under the microscope give the appearance of typically opalized silica with elongated areas of intergrown calcite. The chalcedony which fills the amygdules is banded in most specimens, and there are small spherulites of the same. Mixed with the chalcedony are areas of small quartz grains and large crystals of calcite. The spherulites are formed of radiating fibers. The chlorite occurs as small flakes, and appears to be due to hydrothermal alteration of the augite, replacing the original crystal wholly or in part. Quartz is found towards the center of the chlorite. Sericite is scattered rather profusely through the labradorite. The calcite occurs in both the stringers and amygdules in irregular masses.

Prismatic jointing in Triassic diabase has been known and described from New Jersey, Pennsylvania, and New York. Attempts have been made to determine the cause of the jointing in the exposures in Virginia. Some twenty years ago a comprehensive study of prismatic jointing was made by Sosman[2] in which distinctions were recognized from field studies as between jointings due to contraction, convection, and those due to weathering. In the light of all available evidence bearing upon jointing in the Virginia diabase, it seems that it can best be explained as resulting from contraction on cooling. Using the criteria cited by Sosman in support of the contraction theory, there was observed as follows: (1) the pentagonal nature of the greater

[2] SOSMAN, ROBERT B. *Types of Prismatic structure in igneous rocks.* Jour. Geol. 24: 215–234, 5 figs. 1916.

number of prisms, (2) small diameters of the prisms as compared with those of the Giant's Causeway and the Devil's Tower (the latter attaining as much as six feet) (3) no apparent change in texture from the center to the periphery of the prisms, (4) great irregularity of faces on the prisms, and (5) relative scarcity of convexity and concavity in cross-jointing. The amygdaloidal structure suggests that the diabase is a sheet which was extruded towards the close of Upper Triassic (Keuper) time in Virginia.

PALEONTOLOGY.—*Five new genera of Carboniferous Crinoidea Inadunata.*[1] EDWIN KIRK, U. S. Geological Survey.

Owing to a series of misunderstandings, mischances, and mistakes the genera *Zeacrinus, Woodocrinus, Pachylocrinus, Scaphiocrinus,* and *Graphiocrinus* have been involved in a maze of nomenclatorial difficulties. Springer (1911) was well on the way toward clearing up the situation in part and did extricate *Pachylocrinus* from the confusion, which was his immediate purpose. He suggested the separation of one group of species under a new genus, but unfortunately did not give it a name, referring the species to *Woodocrinus*? instead. Subsequently Springer (1926) threw typical members of this latter group back into *Zeacrinus,* under which they had first been described in the main. This action again made *Zeacrinus* a catch-all for Carboniferous crinoids whose "only stable character," according to Springer (1926, p. 78), "is the heterotomous arm-branching, with mostly uniserial, short and distally quadrangular brachials." It is only fair to state that this paper was written by Springer under most adverse conditions, with seriously impaired health and without access to specimens and limited access to literature. It seems probable that he overlooked his own conclusions of 1911, for otherwise he certainly would have mentioned them and given reasons for their abandonment.

In the present paper a number of species will be considered, most of which have been referred to *Zeacrinus* at one time or other, chiefly by Wachsmuth and Springer and by Springer. To these are added some species that seem referable to the genera here described. It is not my purpose at this time properly to assign to their respective genera the large number of species that at one time or other have been referred erroneously to *Zeacrinus.* In earlier days Meek considered *Zeacrinus* a probable synonym of *Hydreionocrinus.* Meek and Worthen, Shumard, and Lyon considered the possibility that *Zea-*

[1] Published by permission of the Director, Geological Survey, United States Department of the Interior. Received Feb. 1, 1938.

crinus and *Graphiocrinus* were synonyms. Later, Miller and Gurley's species of *Zeacrinus* were about equally divided between *Zeacrinus* and *Phanocrinus*. Some species referred to *Zeacrinus* will fall into *Pachylocrinus*. The reference of many of the described species to their respective genera can best be made after the genera involved are clearly defined, each with a nucleus of characteristic species referred to it. Short of a monographic study of the Inadunata, a treatment such as that given here seems the most feasible method of attack on an admittedly difficult problem. The group more or less centering about *Zeacrinus* was chosen because it seemed to be the one most involved in nomenclatorial difficulties, and the species of which historically were the most uncertain of placement.

An attempt is here made to create generic groups on the basis of genetic relationship and evolutionary trends. In the Carboniferous thousands of specimens of Inadunata are available for study in the collections, representing a long and not greatly interrupted period of geologic time. It should then be possible to segregate lines of descent and express the results in terms of classification. Undue emphasis on one structural feature, such as the ventral sac or the plates of the posterior interradius, is unfortunate. It has been found that combinations of characters, with varying weights given to different factors dependent on the stage in phylogeny, give the most satisfactory results. Such genera do not lend themselves well to placement in analytical charts, but this may be an advantage rather than otherwise. Such genera, however, if properly made, possess the merit of having definite stratigraphic value and can be used intelligibly in the discussion of biologic problems. A discussion of the criteria used in discriminating the genera would be desirable but in itself would prove to be a work of considerable size. The criteria after all are essentially those used by critical workers in the past. In the brief generic diagnosis an attempt is made to present the norm for the genus, with brief indications of permissible variants in structure.

In the lists of species the dates and authors' names alone are given for bibliographic reference, and the complete citations may be found by referring to the bibliography at the end of the paper. No attempt is here made to indicate synonymy of species or quote synonymies hitherto made by authors. Either would be of little value at this time. I have had access to the types of the majority of the species, or reasonably authentic specimens identified by Wachsmuth. In the case of several of the species illustrations are wanting and in others are of poor quality. The types of some of these species have ap-

parently been lost. Many species have been based on immature individuals, and these are particularly difficult to place. Horizons and localities are quoted as given in the original descriptions. Amended citations of stratigraphic horizons are given in parentheses, where available and when known to differ from the original text.

The genotypes of five of the six genera discussed in this paper, *Alcimocrinus*, *Cercidocrinus*, *Eratocrinus*, *Zeacrinus*, and *Linocrinus* are very fully illustrated by Springer (1926). For the illustration of the genotype of *Adinocrinus* one must refer to the original description of Wachsmuth and Springer.

Zeacrinus Troost

Zeaecrinites, nom. nud., Troost, p. 419, 1849; p. 61, 1850.
Zeacrinus Troost, in Hall, p. 544, 1858.
Genotype.—Zeacrinus magnoliaeformis Troost.
Generic diagnosis.—
Crown. Ovoid.
Dorsal cup. Basin-shaped with deeply invaginated base.
IBB. Small, forming bottom of basal pit, covered by column.
BB. Variable in size and shape but typically elongate, lanceolate, taking part in the basal pit.
Post B, when in contact with anal x, greatly elongated.
RR. Radial facet extends full width of R, suture not gaping. Articulating face at high angle.
Anal plates. Variable in size, shape, and arrangement. Typically three plates in cup. Anal x in contact with post B, meeting it on a narrow oblique face. RA penetrates deeply between post B and R post B, sometimes completely separating them. RA meets post B laterally and r post B on a very narrow face. In later phylogenetic stages the anal plates tend to migrate out of the cup. RT sometimes may do so. Anal x may lose contact with post B, its position being taken by RA, which in turn separates from post B.
IBr. One or two in anterior radius. One in other rays.
Arms. Endotomous. Rami laterally appressed, stout, with slightly convex backs. Br quadrangular.
Ventral sac. Pyramidal, with broad base.
Characteristic species of the genus.—

Zeacrinus magnoliaeformis Troost

Zeaecrinites magnoliiformis, nom. nud., Troost, p. 419, 1849.
Zeaecrinites magnoliaeformis, nom. nud., Troost, p. 61, 1850.
Zeacrinus magnoliaeformis Troost, in Hall, p. 544, 1858.
Zeacrinus magnoliaeformis Springer, p. 81, pl. 22, figs. 4–11, 1926.

Geologic and geographic distribution.—Zeacrinus as known is widely distributed in rocks of upper Mississippian age. In the United States it is one of the most characteristic crinoids of the Chester group. In Europe typical species of the genus are known in beds of equivalent age in England and Scotland.

Relationships.—I conceive the ancestor of *Zeacrinus* to be an undescribed genus, the earliest known species of which is found in the Keokuk. The genus carries on in the Borden of Indiana, the Warsaw of the Mississippi Valley, and the St. Louis of the same region. The early history of *Zeacrinus* proper seems to lie in the gap between the St. Louis and Chester. Forms referable to *Zeacrinus* may be expected in the Pennsylvanian as the genetic line continued to the Permian, *Parabursacrinus* of this age differing little from *Zeacrinus* other than in the structure of the posterior interradius.

Adinocrinus, n. gen.

Genotype.—*Zeacrinus nodosus* Wachsmuth and Springer.

Generic diagnosis.—

Crown. Expanding slightly to level of II A x, then more rapidly to level of III A x, then curving inward.

Dorsal cup. Depressed basin-shaped, small in comparison with the size of the crown, sharply pentagonal in outline.

IBB. In bottom of central depression, covered by column or slightly projecting beyond it.

BB. Relatively very small, typically showing as triangles separated by the RR, which in such case contact with the IBB. Post B larger than the others. In one specimen (young?) three of the BB meet laterally, but by very narrow faces.

RR. Proportionally very large. Radial facet extends full width of R. Suture gaping. Articulating face at high angle and very deep.

Anal plates. RA long and narrow, sometimes touching, sometimes not touching r post B; meeting post B on long lateral face. Anal x usually high in cup, separated from post B and lying in line with RA, on which it rests. RT resting on sloping upper right shoulder of anal x and either on the truncated upper face of RA or a narrow facet on upper left shoulder of post R.

IBr. Five in anterior radius in the three specimens seen. One in all other radii. IBr_1 of ant. R very high with oblique upper face.

Arms. Isotomous, with two divisions above the main dichotom. The rami are very stout, with rounded backs and composed for the most part of quadrangular Br. Below the finials many of the Br show a pronounced taper, but in all cases the Br extend the full width of the ramus. All axillaries are nodose, and the proximal Br of each series is larger than the succeeding Br and is strongly convex to nodose. This applies to all three species of which the arms are known. Below the III A x there are processes on the lateral margins of the Br which interlock with similar processes of the Br of the juxtaposed ramus.

Ventral sac. Unknown.

Characteristic species of the genus.—

Adinocrinus compactilis (Worthen) n. comb.

Zeacrinus compactilis Worthen, in Meek and Worthen, p. 536, pl. 21, figs. 5a, b, 1873. "Lower Carboniferous, Cumberland County, Kentucky." (Figured on plate labeled "Chester Beds."); Wachsmuth and Springer, p. 128 (351), 1880; Wachsmuth and Springer, p. 243 (167), 1886.

Adinocrinus nodosus (Wachsmuth and Springer), n. comb.

Zeacrinus nodosus Wachsmuth and Springer, p. 243 (167), pl. 6, fig. 9; pl. 9, fig. 3, 1886. "Keokuk limestone." Whites Creek Springs, near Nashville, Tenn., (New Providence equivalent).

Geologic and geographic distribution.—The genus *Adinocrinus* is known only from the New Providence formation, lower Mississippian, of Kentucky and an approximately equivalent horizon at Whites Creek Springs, near Nashville, Tenn.

Relationships.—With a dorsal cup resembling *Zeacrinus* near the end of its line, and with arms of such extraordinary character, one is at a loss to indicate relationships or point out any genus which might serve as an antecedent type. I do not think *Adinocrinus* should be placed in the same family as *Zeacrinus*. The pentagonal cup and the narrow posterior interradius were probably induced by the unusually heavy arms. The narrow posterior interradius combined with the upward migration of anal plates, a tendency common to many Inadunate lines, has given us a cup strikingly like *Zeacrinus* of the later type. There all resemblance to *Zeacrinus* and its allies ceases. If we lack an antecedent type there is a later type that has some of the outstanding peculiarities of *Adinocrinus*. *Protencrinus* Jaekel (1918) from rocks of Pennsylvanian age in Russia has similar small subtriangular BB separated by the RR, which extend down to the IBB. Very heavy arms with cuneate nodose Br also favor the relationship. In *Protencrinus* the arms remain simple above the first dichotom, but this is permissible, as a reduction in the number of rami can be demonstrated in other crinoid lines. In *Protencrinus* the anal plates have passed entirely out of the cup, which would be expected in a descendant of *Adinocrinus*. A dorsal cup from the Permian of Timor has been referred to *Protencrinus* by Wanner (1924), and a dorsal cup from the Viséan of Germany has been identified as *Protencrinus* by Schmidt (1930).

Alcimocrinus, n. gen.

Genotype.—Zeacrinus girtyi Springer.

Generic diagnosis.—

Crown. Subcylindrical, slightly spreading distad.

Dorsal cup. Depressed basin-shaped, invaginated at base.

IBB. Small, in central depression, concealed by column.

BB. Subequal, relatively large.

RR. Radial facet extending full width of R, suture not gaping.

Anal plates. RA rests subequally on sloping shoulders of post and r post BB, not penetrating deeply between them. Anal x rests on the wide, horizontal distal face of post B.

IBr. Two in all rays, but more might be expected in ant. R.

Arms. Endotomous. The outer portion of the half-ray is essentially an arm-trunk, very stout and reminding one of certain Camerate types, such as *Ctenocrinus*. The rami given off to the inner side of the ray are more numerous than in any genus of this group and resemble ramules more than true arm branches. The Br of the main arm-trunks are quadrangular in the main but with interspersed cuneate ossicles. The Br of the side rami are quadrangular.

Ventral sac. The ventral sac is long and club-shaped, extending beyond the tips of the arms.

Characteristic species of the genus.—

Alcimocrinus girtyi (Springer), n. comb.

Zeacrinus girtyi Springer, p. 84, pl. 23, figs. 9, 9a, 1926. "Morrow formation of the basal Pennsylvanian; near Crittenden in northeastern Oklahoma." (Wapanucka limestone *fide* Ulrich.)

Geological and geographical distribution.—The only known species of the genus is found in the early Pennsylvanian (Morrow group) of Oklahoma.

Relationships.—*Alcimocrinus* differs from *Zeacrinus* in important respects. The dorsal cup, though depressed basin-shaped, has essentially the structure of the early Mississippian species here referred to *Eratocrinus*, as pointed out by Springer (1926, p. 85). The presence of two IBr in the rays other than ant. R is of importance in a type as late as this. The long club-shaped ventral sac is also reminiscent of *Eratocrinus*, though considerably longer than in that genus. The arms of *Alcimocrinus*, which are in effect arm-trunks with lateral ramules, differentiate the genus from any other known. *Paraburs acrinus* Wanner of the Permian, which Wanner probably with justice derives from *Zeacrinus*, is essentially *Zeacrinus* as to arms and shape of crown. It is probable that *Alcimocrinus* lies outside the *Zeacrinus* line, and the two are to be derived from a common but fairly remote ancestor.

Cercidocrinus, n. gen.

Genotype.—*Poteriocrinus bursaeformis* White.

Generic diagnosis.—

Crown. Spreading gradually from base.

Dorsal cup. Turbinate, not invaginated at base.

IBB. Plainly visible in lateral view, relatively large.

BB. Subequal, of nearly same height as breadth.

RR. Radial facet the full breadth of the R, suture not gaping.

Anal plates. Three in cup, RA resting subequally on upper sloping shoulders of post and r post BB, x resting on horizontal wide truncated distal face of post B.

IBr. Three to four or more in ant. radius, one or two in other radii. A single IBr (other than in the ant. R) seems normal for Burlington time, though exceptions have been seen in single rays. In the Kinderhook one new species has two in all rays, except the anterior, which has seven.

Arms. Endotomous, long, rounded, sides not flattened, showing that the rami were not normally closely appressed. Br very low, quadrangular.

Ventral sac. Unknown.

Characteristic species of the genus.—

Cercidocrinus blairi (Miller and Gurley), n. comb.

Poteriocrinus blairi Miller and Gurley, p. 61, pl. 4, figs. 1, 2, 1895. "Burlington group, at Sedalia, Missouri."

Cercidocrinus bursaeformis (White), n. comb.

Poteriocrinus bursaeformis White, C. A., p. 10, 1862. "Lower division of the Burlington limestone, Burlington, Iowa."

Zeacrinus bursaeformis Wachsmuth and Springer, p. 128 (351), 1880.
Woodocrinus bursaeformis Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? bursaeformis Springer, p. 147, 1911.
N. Gen. bursaeformis Springer, p. 148, 1911.
Zeacrinus bursaeformis Springer, p. 79, pl. 21, fig. 1, 1926.

Cercidocrinis cirrifer (Laudon), n. comb.

Pachylocrinus cirrifer Laudon, p. 63, pl. 6, figs. 3, 4, 1933. "Gilmore City formation, Gilmore City, Iowa."

Cercidocrinus fimbria (Laudon), n. comb.

Pachylocrinus fimbria Laudon, p. 64, pl. 5, figs. 2, 3, 1933. "Gilmore City formation, Gilmore City, Iowa."

Cercidocrinus infrequens (Laudon and Beane), n. comb.

Zeacrinus infrequens Laudon and Beane, p. 257, pl. 17, figs. 11, 12, 1937. "Hampton formation, Le Grand, Iowa."

Cercidocrinus? sampsoni (Miller and Gurley), n. comb.

Poteriocrinus sampsoni Miller and Gurley, p. 65, pl. 4, figs. 9, 10, 1895. "Chouteau limestone at Sedalia, Missouri." (Dorsal cup only.)

Geological and geographic distribution.—*Cercidocrinus* is known only from the Kinderhook, Chouteau (?), and Burlington formations of Iowa and Missouri. It reached its maximum size in the lower Burlington, and this seems to have been its latest appearance. The maximum number of species has been found in the Kinderhook. In addition to those listed there are at least two additional new species from that horizon.

Relationships.—It is difficult to draw conclusions in regard to the interrelationships of *Cercidocrinus*. Lacking knowledge of its ontogeny or its Upper Devonian antecedents we can only attempt a placement according to our knowledge of the behavior of similar crinoid stocks. Its relationships seem to be nearest to forms commonly referred to *Pachylocrinus*.

In arm structure *Cercidocrinus* most nearly resembles *Eratocrinus* from which in its known characters its most notable difference is the turbinate dorsal cup and the prominent infrabasals. The crown has a different habit, spreading gradually distad, and the rami were not tightly appressed, as against the pyriform crown of *Eratocrinus* with its normally tightly packed rami. In the form of its dorsal cup *Cercidocrinus* approaches the British genus *Woodocrinus*, from which it chiefly differs in the structure of the arms, In *Woodocrinus* the arms are relatively short, stout, tapering rapidly distad. and isotomous in their division. *Coeliocrinus* differs chiefly from *Cercidocrinus* in its cuneate brachials, approaching a biserial condition. The ventral sac of *Cercidocrinus* being unknown, comparisons with that of *Coeliocrinus* are out of the question. The stress laid on the character of the distal portion of the ventral sac in classification among the Carboniferous Inadunata has been greatly overdone. Such structures should be made subsidiary and considered only as accessory features in evaluating a genus.

Eratocrinus, n. gen.

Genotype.—Zeacrinus elegans Hall.

Generic diagnosis.—

Crown. Elongate, usually with closely appressed arms, typically inverted pyriform in shape.

IBB. Small, concealed in basal pit.

BB. Of medium size, helping form the basal depression.

RR. Radial facet full width of radial, suture not gaping.

IBr. Two to five in the anterior radius, invariably one in other rays in all known species. [The two IBr in the r post R of fig. 2a, pl. 21 (Springer, 1926) are incorrect.]

Arms. Endotomous with slightly convex to rounded backs, composed of unusually low, quadrangular Br. Rami laterally appressed. Early species of *Eratocrinus* or young specimens may be expected to show isotomous arm divisions, with but one division above the main dichotom. Such structures are to be found in the lower Burlington *Eratocrinus pikensis* (Worthen) and *Eratocrinus scoparius* (Hall). In *E. scoparius* the arms usually bifurcate but once above the dichotom and are isotomous. Rays are to be found, however, where there is a second division above the dichotom, producing an endotomous structure. Judging from the figure of *E. pikensis*, a similar condition obtains in that species. It seems reasonably certain that the evolutionary stage preceding endotomy is isotomy, with a single division above the primary dichotom.

Anal plates. Three in cup. RA not penetrating deeply between post and r. post BB. Anal x resting on wide horizontal distal face of post. B.

Ventral sac. Moderately long, typically not reaching to tips of arms, club-shaped.

Column. Pentagonal with rounded angles, to round. Long, relatively stout cirri borne in whorls to within a short distance of the crown.

Characteristic species of the genus.—

Eratocrinus commaticus (Miller), n. comb.

Zeacrinus commaticus Miller, p. 36, pl. 5, figs. 10, 11, 1891. "Keokuk group, at Booneville, Cooper County, Missouri." (Warsaw).—Springer, p. 80, pl. 22, figs. 1–3a, 1926.

Eratocrinus coxanus (Worthen), n. comb.

Zeacrinus coxanus Worthen, p. 27, 1882.—Worthen, p. 302, pl. 28, fig. 1, 1883. "Upper beds of the Keokuk limestone, Hamilton, Illinois."
Woodocrinus coxanus Wachsmuth and Springer, p. 302 (226), 1886.

Eratocrinus elegans (Hall), n. comb.

Zeacrinus elegans Hall, p. 547, pl. 9, figs. 1, 2, 1858. "Burlington limestone, Burlington, Iowa."—Wachsmuth and Springer, p. 128 (351), 1880.
Woodocrinus elegans Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? elegans Springer, p. 147, 1911.
N. Gen. elegans Springer, p. 148, 1911.
Zeacrinus elegans Springer, p. 80, pl. 21, figs. 2–4, 1926.

Eratocrinus faggi (Rowley and Hare), n. comb.

Zeacrinus faggi Rowley and Hare, p. 103, pl. 2, fig. 20, 1891. "Upper Burlington limestone in Spencer Creek, 2 miles north of Curryville, Missouri."

Eratocrinus orbicularis (Hall), n. comb.

Scaphiocrinus orbicularis Hall, p. 311, 1861.—Hall, p. 7, 1861a. "Keokuk limestone, Keokuk, Iowa."—Hall, pl. 5, figs. 7–9, 1872.
Eupachycrinus? orbicularis Wachsmuth and Springer, p. 138 (361), 1880.
Eupachycrinus orbicularis Wachsmuth and Springer, p. 249 (173), 1886.
Zeacrinus orbicularis Wachsmuth and Springer, p. 334 (Index), 1886.—Worthen, p. 97, pl. 14, figs. 2, 2a, 1890.

Eratocrinus pikensis (Worthen), n. comb.

Zeacrinus pikensis Worthen, p. 29, 1882.—Worthen, p. 304, pl. 30, fig. 3, 1883. "Lower part of the Burlington limestone, Montezuma, Pike County, Illinois."
Scaphiocrinus pikensis Wachsmuth and Springer, p. 237 (161), 1886.

Eratocrinus ramosus (Hall), n. comb.

Zeacrinus ramosus Hall, p. 548, pl. 9, fig. 3, 1858. "Burlington limestone, Burlington, Iowa." (Upper Burlington).—Wachsmuth and Springer, p. 129, 1880.
Woodocrinus ramosus Wachsmuth and Springer, p. 242 (166), 1886.—Springer, p. 147, 1911.

Eratocrinus raymondi (Laudon and Beane), n. comb.

Pachylocrinus raymondi Laudon and Beane, p. 255, pl. 18, fig. 4, 1937. "Hampton formation, Timber Creek quarry, 2 miles west of Le Grand, Iowa."

Eratocrinus sacculus (White), n. comb.

Zeacrinus sacculus White, p. 12, 1862.
Zeacrinus sacculus var. *concinnus* White, p. 13, 1862. "Upper division of the Burlington limestone, Burlington, Iowa."

Eratocrinus salemensis (Miller and Gurley), n. comb.

Zeacrinus salemensis Miller and Gurley, p. 37, pl. 3, fig. 17, 1894. "Keokuk group at Salem, Indiana."

Eratocrinus scoparius (Hall), n. comb.

Zeacrinus scoparius Hall, p. 305, 1861.—Hall, p. 8, 1861a. "Burlington limestone, Burlington, Iowa." (Probably lower Burlington.)

Eratocrinus serratus (Meek and Worthen), n. comb.

Zeacrinus serratus Meek and Worthen, p. 151, 1869.—Meek and Worthen, p. 428, pl. 1, fig. 6, 1873. "Burlington group at Burlington, Iowa." (Upper Burlington).—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus serratus Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? serratus Springer, p. 147, 1911.
N. Gen. serratus Springer, p. 148, 1911.

Eratocrinus troostanus (Meek and Worthen), n. comb.

Zeacrinus troostanus Meek and Worthen, p. 390, 1861.—Meek and Worthen, p. 186, pl. 16, fig. 2, 1866. "Burlington limestone, Cedar Creek, Warren County, Illinois."—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus troostanus Wachsmuth and Springer, p. 242 (166), 1886.

Woodocrinus? troostanus Springer, p. 147, 1911.
N. Gen. troostanus Springer, p. 148, 1911.

Geographic and geologic ranges.—*Eratocrinus* as known has a geologic range in the lower Mississippian from the Kinderhook to the Warsaw inclusive. It is doubtful if this geologic range will be extended greatly by future finds. Geographically the genus is widely distributed in the upper Mississippi and Ohio Valleys, having been found in Iowa, Illinois, Missouri, Tennessee, and Indiana. As represented in the collections and based on field experience, the genus was most prolific, both as to number of species and individuals, in the Burlington. As reflected in the specific separations, this was likewise the time of maximum variability. Maximum size was reached in Keokuk time.

Besides the species here listed there are interesting new forms from horizons of approximately Keokuk age in Tennessee and Indiana. From Whites Creek Springs, near Nashville, Tennessee, there is a set of typical arms, as well as several dorsal cups. The largest of these cups has an approximate diameter of 25 mm. From the Borden group of Indiana, near New Ross, is a complete crown some 80 mm. in height and with a dorsal cup 25 mm. in diameter. In the upper Borden of Indian Creek, Montgomery County, Indiana, is a new species referable to *Eratocrinus*.

Relationships.—*Eratocrinus* resembles *Zeacrinus* superficially in the shape of the dorsal cup and in the possession of endotomous arm structures. The crown of *Eratocrinus* is elongate inverted pyriform, as against the ovate shape of *Zeacrinus*. The cup of *Eratocrinus* is relatively deeper than in *Zeacrinus*, being bowl-shaped rather than depressed basin-shaped. The arm facets in *Eratocrinus* are shallower than in *Zeacrinus* and are nearly horizontal as against the high-angled facets of *Zeacrinus*. The BB of *Zeacrinus* are typically elongate, the post B being disproportionally so. RA in *Zeacrinus* penetrates deeply between post and R post BB, meeting post B on a very narrow face, if at all. RA in *Eratocrinus* rests subequally on the upper sloping shoulders of post and r post BB. Anal x in *Eratocrinus* rests on the broad horizontal truncated distal face of post B. In *Zeacrinus* x either does not contact with post B, or when it does it usually rests on a very narrow oblique face. The arms of *Eratocrinus* are proportionally longer and more slender than in *Zeacrinus*. The ventral sac of *Eratocrinus* is elongate club-shaped as against broad-based pyramidal sac of *Zeacrinus*. Aside from formal differences a casual glance will serve to separate the dorsal cups, or sets of arms of the two genera.

I do not believe that *Eratocrinus* and *Zeacrinus* are nearly related. I conceive the ancestor of *Zeacrinus* to be an undescribed genus, the earliest known species of which is found in the Keokuk, and which is more unlike *Eratocrinus* than is *Zeacrinus*. Very young specimens of *Eratocrinus elegans* in general habit resemble *Zeacrinus* more than do the adults, though, of course, such details as the relative positions and shapes of the plates of the dorsal cup are quite unlike *Zeacrinus*.

Linocrinus, n. gen.

Genotype.—Linocrinus wachsmuthi, n. sp.

Generic diagnosis.—

Crown. Expanding gradually, then incurving distad.

Dorsal cup. Bowl-shaped, flattened and slightly invaginated at base. Plates typically rugose in adult stages.

IBB. Small, in central depression, concealed by column.

BB. Subequal, taking part in the flattened basal area, then flexing upward to help form the sides of the cup.

RR. Radial facet extending full width of R, suture gaping.

Anal plates. Three in cup. RA rests subequally on sloping shoulders of post and r post BB. Anal x rests on horizontal distal face of post B.

IBr. Three to five in ant. R, one in all others. The IBr_1 is sharply keeled.

Arms. Endotomous, except in anterior radius, which is isotomous as seen. Rami relatively stout, frequently with median longitudinal keels or nodose Br. In some species the Br of juxtaposed rami tend to interlock by lateral processes. Br quadrangular, but somewhat cuneate.

Ventral sac. In the type species extending to near the tips of the arms and turned back on itself in the distal portion.

Characteristic species of the genus.—

Linocrinus arboreus (Worthen), n. comb.

Zeacrinus arboreus Worthen, p. 534, pl. 20, fig. 5, 1875. "St. Louis limestone? near Huntsville, Alabama." (Probably Gasper formation of the Chester group, Monte Sano, east of Huntsville, Alabama.)

Poteriocrinus (*Pachylocrinus*) *arboreus* Wachsmuth and Springer, p. 116 (339), 1880.

Woodocrinus arboreus Wachsmuth and Springer, p. 242 (166), 1886.

Linocrinus asper (Meek and Worthen), n. comb.

Zeacrinus asper Meek and Worthen, p. 150, 1869.—Meek and Worthen, p. 430, pl. 1, fig. 7, 1873. "Upper division of Burlington group, Burlington, Iowa." (Lower Burlington)

Pachylocrinus asper Wachsmuth and Springer, p. 116, 1880.

Zeacrinus asper Wachsmuth and Springer, p. 128, 1880.

Woodocrinus asper Wachsmuth and Springer, p. 242, 1886.

Linocrinus cariniferous (Worthen), n. comb.

Zeacrinus cariniferous Worthen, p. 535, pl. 20, fig. 4, 1873, "St. Louis limestone? near Huntsville, Alabama." (Probably Gasper formation of the Chester group, Monte Sano, east of Huntsville, Alabama.)

Coeliocrinus cariniferous Wachsmuth and Springer, p. 133 (358), 1880.

Linocrinus compactus (Laudon), n. comb.

Zeacrinus compactus Laudon, p. 66, pl. 5, figs. 4, 5, 1933. "Gilmore City formation, Gilmore City, Iowa."

Linocrinus lautus (Miller and Gurley), n. comb.

Poteriocrinus lautus Miller and Gurley, p. 30, pl. 2, figs. 18, 19, 1896. "Keokuk group, at Booneville, Missouri." (Warsaw)

Linocrinus penicillus (Meek and Worthen), n. comb.

Scaphiocrinus penicillus Meek and Worthen, p. 142, 1869.—Meek and Worthen, p. 414, pl. 2, fig. 7, 1873. "Upper division of the Burlington group, at Burlington, Iowa."—Wachsmuth and Springer, p. 113 (336), 1880.

Linocrinus perangulatus (White), n. comb.

Zeacrinus perangulatus White, p. 11, 1862. "Upper division of the Burlington limestone, Burlington, Iowa."
Pachylocrinus perangulatus Wachsmuth and Springer, p. 116 (339), 1880.
Woodocrinus perangulatus Wachsmuth and Springer, p. 242 (166), 1886.

Linocrinus praemorsus (Miller and Gurley), n. comb.

Scaphiocrinus praemorsus Miller and Gurley, p. 48, pl. 8, fig. 11, 1890. "Keokuk group, in Washington County, Indiana."

Linocrinus scobina (Meek and Worthen), n. comb.

Zeacrinus scobina Meek and Worthen, p. 149, 1869.—Meek and Worthen, p. 426, pl. 1, fig. 2, 1873. "Upper division of the Burlington group, Burlington, Iowa."—Wachsmuth and Springer, p. 129 (352), 1880.
Woodocrinus scobina Wachsmuth and Springer, p. 242 (166), 1886.
Woodocrinus? scobina Springer, p. 147, 1911.
N. Gen. scobina, Springer, p. 148, 1911.

Linocrinus spinuliferus (Worthen), n. comb.

Poteriocrinus spinuliferus Worthen, p. 27, 1884.—Worthen, p. 86, pl. 14, fig. 3; p. 90, pl. 17, figs. 1, 1a, 1890. "Chester limestone near Columbia, Monroe County, Illinois."

Linocrinus wachsmuthi, n. sp.

Ste. Genevieve formation of the Chester group, about 7 miles south of Huntsville, Alabama.

Geologic and geographic distribution.—The genus *Linocrinus* as recognized at present extends from the Kinderhook to the Chester and has a geographic distribution coextensive with the Mississippian deposits. It seems to be one of the most ubiquitous of the Inadunate genera.

Relationships.—The norm for the genus is a line of small species that has a remarkable similarity of structure, form, and ornamentation from the earliest appearance of the genus to the end. The interrelationships of Linocrinus seem to be with *Decadocrinus* and *Pachylocrinus*. *Decadocrinus* with its rugose plates, keeled Br, and gaping suture seems to come nearest to *Linocrinus*. An endotomous *Decadocrinus* with a few minor changes would give *Linocrinus*, just as a *Decadocrinus* with two isotomous divisions above the main dichotom is essentially *Pachylocrinus*. From *Eratocrinus*, *Linocrinus* differs in the rugosity of the cup plates, its keeled Br, and its well-marked gaping suture between the R and IBr_1.

Linocrinus wachsmuthi, n. sp.

Types.—As types of the species I have chosen part of the specimens figured by Springer (1926) as illustrating "*Zeacrinus arboreus* Worthen."

As holotype I have chosen the specimen illustrated as figure 5, plate 16, and as paratypes the specimens illustrated as figures 4 and 6 on the same plate. The types are in the Springer collection in the United States National Museum. The genotype is dedictated to Charles Wachsmuth, to whose tireless efforts in the field and study we owe a great part of our knowledge of American crinoids. The specimens chosen as types were collected by him and his wife.

Description.—The species has a small, compact crown expanding somewhat distad. The dorsal cup is basin-shaped with a flattened base. The plates of the cup are rugose, the surface ridges falling into definite but interrupted patterns. Ridges extend from center to center of the BB and from the centers of the BB across on the RR. There is usually a well-defined median, vertical ridge on each radial.

The IBB are small and concealed by the column. The BB are large, taking part in the flattened basal area, and flexing upward to form part of the sides of the cup. The RR are large with a straight articulating facet extending the full width of the radial. The suture with the IBr is broadly gaping.

There are from 4 to 5 IBr in the ant. R, the first primibrach being very large. In the other rays there is but one IBr to the ray. The first primibrach is traversed by a median vertical keel. The arms are relatively short, stout, and endotomous. Two divisions above the main dichotom are usual. The Br to the second division are usually traversed by a longitudinal keel. The Br are quadrangular, with a slight taper in the lower portions of the arm. Distad the Br are cuneate. Laterally there may be spinous processes that tend to interlock with similar processes on juxtaposed rami.

The ventral sac is somewhat shorter than the arms, reflexed in the distal portion, and with three rather prominent, median rows of plates that tend to be spinous.

Horizon and locality.—The main locality for *Linocrinus wachsmuthi* is about seven miles south of Huntsville, Alabama, near the foot of the ridge east of the road. They occur in the Ste. Genevieve formation of the Chester group. Having been at the type locality with Mrs. Wachsmuth I am able to give a locality somewhat better than the stereotyped "Huntsville, Alabama."

Relationships—From *Linocrinus cariniferous* (Worthen) and *Linocrinus arboreus* (Worthen) from stratigraphically higher beds of the same region, *Linocrinus wachsmuthi* can be distinguished most readily by the greater rugosity of the cup-plates, the plates of the later species being tumid with depressions at the angles, or with obscure, rounded ridges. Worthen's type of *Linocrinus arboreus* is either a young specimen or a small species. There are no marked juvenile characters in the specimen, judging from casts of the type, but it may well be the young of *L. cariniferous*. The arms of *L. arboreus* are relatively stouter than in *L. wachsmuthi*, and the Br are almost rectangular in outline, despite the original figure. The dorsal cup of *L. arboreus* is relatively much higher than in *L. wachsmuthi*.

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BOTANY.—Raouliopsis (*Asteraceae*), *a new genus of "vegetable sheep" from the high páramos of Colombia.*[1] S. F. BLAKE, Bureau of Plant Industry.

The "vegetable sheep" of New Zealand—species of *Haastia* and *Raoulia*, genera belonging to two different tribes of Asteraceae—are among the oddities of the vegetable kingdom. The repeatedly branched stems, only a few inches or sometimes a couple of feet high and about as thick as the finger with their dense covering of linear to cuneate, densely pilose, many-ranked, long-persistent leaves, are compacted into convex or flattish, rounded or amorphous, brownish or greenish cushions, sometimes as big as an ordinary sofa and so dense that the point of a pencil or "even of a pin" cannot be thrust between the branches.[2] The small or medium flower heads, in both genera lacking rays but provided with filiform pistillate florets, are borne singly[3] at the tips of the branches, sunken among the leaves and almost hidden by them. The extreme compactness of the plants and their dense covering of hairs are obviously correlated with their habitat, bare rocky hill slopes at about 40° S. latitude, where the hot dry winds of summer and the winter's snows, low temperatures, and violent gales expose them to a perpetual alternation of desert and arctic conditions. These extreme modifications of structure, however, are specific rather than generic, and are shown by only about 9

[1] Received January 6, 1938.

[2] According to E. Low, Trans. N. Z. Inst. 32: 151. 1899, in her account of the vegetative organs of *Haastia pulvinaris*.

[3] Or, in a single variety (*Raoulia grandiflora* var. *fasciculata* (J. Buch.) Cheesem.), in 3's.

species[4] of the two genera. The remaining species (3 in *Haastia*, 14 in *Raoulia*), although revealing in their low stature, small, often leathery leaves, and usually dense hairy covering the result of response to similar but less extreme environments, are by no means as outstanding in appearance in their groups.

It now appears that the high páramos of the Sierra Nevada de Santa Marta in northeastern Colombia harbor two species so closely similar to the *Raoulia eximia* group not only in habit but also in most technical characters that if they were found in New Zealand they might readily be placed in that genus, although as somewhat aberrant members. Differences in the pappus (in the only species in which the flowers are known) of some taxonomic importance, reinforced by the occurrence of these species in a region so remote as Colombia, quite without phytogeographical alliances with New Zealand, make it advisable to place them in a separate genus and to regard their resemblance in habit to the *Raoulia eximia* group, a resemblance so close that it amounts to virtual identity, as the result of the action of similarly extreme habitats on two old branches of the *Gnaphalium* stock rather than as an indication of very close genetic relationship.

Raouliopsis Blake, gen. nov.

Celaena Wedd. Chlor. And. 1: 231. 1857, nomen provisorium.

Fruticuli densissime caespitosi, pulvinos fulvescentes efformantes; caules v. rami numerosissimi densissime compacti suberecti foliis dense obtecti 5–12 mm crassi apice mammiformes; folia alterna densissime conferta multifaria linearia v. oblonga sessilia 1–3-nervia integerrima patentia infra submembranacea apice subcoriacea subtus in margine et intus infra apicem glabra alibique densissime fulvopilosa, pilis comam cuneiformem efformantibus; capitula apice ramorum solitaria v. plura parva sessilia inter folia immersa. Capitula heterogama disciformia ca. 26-flora, floribus fem. quam flor. hermaph. verisim. fertilibus paullo pluribus; involucri ca. 3-seriati paullum gradati phyllaria linearia acuta subchartacea lutescenti-albida, apice scarioso lutescenti-albido v. albo erectiusculo non conspicuo; receptaculum parvum nudum planum; flores fem. 15, corolla filiformi breviter inaequaliterque 5-dentata, stylo exserto, achenio oblongo obscure angulato 4–5-nervio glabro, pappi setis 1-seriatis 12–15 subcapillaribus apice non incrassatis hispidulis prope basim nudis basi ima connatis; flores hermaph. 11 fertiles?, corolla anguste cylindrico-infundibuliformi 5-dentata, achenio oblongo 4-nervio glabro, pappi setis 1-seriatis ca. 13-15 anguste linearibus manifeste complanatis quam eis fl. fem. subtriplo latioribus acutis v. acuminatis hispidulis prope apicem hispidulo-subciliatis apice non incrassatis basi

[4] *Haastia pulvinaris* Hook. f. (tribe *Astereae*); *Raoulia eximia* Hook. f., *R. mammillaris* Hook. f., *R. goyeni* T. Kirk, *R. rubra* J. Buch., *R. buchanani* T. Kirk, (?) *R. loganii* (J. Buch.) Cheesem., (?) *R. bryoides* Hook. f., *R. haastii* Hook. f. (tribe *Gnaphalieae*). These species are listed primarily on the basis of the descriptions in Cheeseman's *Manual of the New Zealand Flora*, ed. 2; I have examined only *H. pulvinaris* and *R. eximia*.

per ⅛–¼ longit. inaequaliter connatis; styli rami fl. hermaph. oblongi erecti truncati dorso et apice minute papillosi; stamina 5 appendicibus triangularibus acutis v. acuminatis donata, basi alte sagittato-auriculata auriculis angustis acuminatis liberis.—Species typica *R. seifrizii*, sp. nov.

This genus is closely allied to *Raoulia* Hook. f., of New Zealand, the more compact species of which genus it very closely simulates in habit. The material available is unfortunately very scanty. The description of the floral characters given above is based on the dissection of the single head containing flowers found on the type sheet of *R. seifrizii;* all the other heads on this sheet have lost their flowers. The floral characters of *R. pachymorpha* are unknown except for those furnished by a few achenes of pistillate flowers from which the corollas have fallen. The principal distinctive characters separating it from *Raoulia* are furnished by the pappus. In *Raouliopsis* the pappus of the pistillate and hermaphrodite flowers differs decidedly, that

Fig. 1.—*a–j, Raouliopsis seifrizii*, from the type; *a*, head with surrounding leaves somewhat separated, ×2; *b*, pistillate flower, ×7; *c*, disk achene with pappus, ×7; *d*, disk corolla, ×7; *e*, stamen, ×15; *f*, style of disk flower, ×15; *g*, leaf, upper side, ×2½; *h*, leaf, lower side, ×2½; *i*, leaf, upper side, the hairs removed to show venation, ×2½; *j*, tip of leaf with hairs removed, ×5; *k–m, Raouliopsis pachymorpha*, from *Schlim* 1002; *k*, leaf, upper side, ×2½; *l*, leaf, lower side, ×2½; *m*, leaf with hairs removed, ×2½.

of the pistillate flowers being composed of about 12–15 subcapillary hairs, shortly connate at base and deciduous in a ring, that of the hermaphrodite flowers of about the same number of distinctly flattened bristles, about three times as wide as those of the pistillate flowers, hispidulous-subciliate at apex and connate for about ⅛ to ¼ their length. In *Raoulia* two groups are recognized based on the structure of the pappus. In the subgenus *Psychrophyton* Beauverd (section *Imbricaria* Benth. & Hook.) the pappus bristles are 15–25, 1-seriate, decidedly flattened, free and naked at base, toward apex thickened and clavate-papillose. In the subgenus *Euraoulia* Beauverd (section *Leptopappus* Benth. & Hook.) the pappus hairs are much more numerous (about 50–150), several-seriate, very slender, subfasciculate, naked below, above hispidulous and at apex loosely barbellate. In both groups the pappus in the female and hermaphrodite flowers is similar.

Heads solitary at tips of branches; leaves linear, 1-nerved below, rounded and not widened at apex; branches including leaves about 5–8 mm thick. 1. *R. seifrizii.*

Heads clustered at tips of branches; leaves oblong, 3-nerved below, subtruncate or broadly rounded and slightly widened at apex; branches including leaves 7–12 mm thick. 2. *R. pachymorpha.*

Raouliopsis seifrizii Blake, sp. nov.

Fruticulus pulvinos fulvos rotundatos in specimibus visis 8 cm diam. et ca. 1.5 cm altos efformans, ramis inter folia densissime conferta longe pilosis; folia linearia apice rotundata sessilia basi non angustata plana 6–6.5 mm longa 1–1.2 mm lata, per ¾ longit. submembranacea in margine scariosa lutescenti-albida 1-nervia, in dorso margine glabro excepto dense pilosa in ventre glabra, apice viridia subcoriaceo-herbacea 3-plinervia supra dense subtus densissime pilosa, pilis ca. 2 mm longis rectis sicc. tortilibus comam cuneiformem efformantibus; capitula apicibus ramorum solitaria sessilia inter folia immersa oblongo-campanulata ca. 5.5 mm alta 2.8 mm crassa; involucri flores subaequantis phyllaria lanceolata acuminata ca. 0.5 mm lata chartacea lutescenti-albida supra in margine et in apice anguste scariosa erecta, exteriora basi longe pilosa interiora glabra; corollae fl. fem. ut videtur pallide brunneae glabrae 1.8 mm longae, dentibus inaequalibus triangularibus acutis apice in pilum brevem desinentibus; corollae fl. hermaph. ut videtur pallide brunneae subcylindricae sursum parum ampliatae glabrae 2.9 mm longae, dentibus 5 triangularibus acutis; achaenia fl. fem. anguste oblonga obscure angulata ad apicem paullum contracta 4–5-nervia glabra 0.7 mm longa, pappi setis ca. 12–15 subcapillaribus hispidulis basi nudis subaequalibus 3 mm longis, paucis brevioribus exceptis; achaenia fl. hermaph. oblonga sub-4-angulata 4-nervia glabra 0.6 mm longa, pappi setis ca. 13–15 anguste paleiformibus linearibus 3.2 mm longis ca. 0.1 mm latis manifeste complanatis quam eis fl. fem. triplo latioribus hispidulis in apice non dilatato hispidulo-subciliatis per ⅛–¼ longit. connatis flavescenti-albidis; styli rami (fl. hermaph.) oblongis erectis 0.4 mm longis.

COLOMBIA: Páramos of the Sierra Nevada de Sante Marta, about 30 miles inland from Dibulla, Dept. Magdalena, alt. ca. 4875 m (16,000 ft.), July 1932, *William Seifriz* 516 (type no. 1,572,506, U. S. Nat. Herb.).

Raouliopsis pachymorpha (Wedd.) Blake

Oligandra pachymorpha Wedd. Chlor. And. 1:230. 1857.
Celaena pachymorpha Wedd. Chlor. And. 1: 230. 1857, as syn.

COLOMBIA: Sierra Nevada, "Prov. of Río Hacha,"[6] alt. 4115 m ("13,500 ft."), March, 1846–52, *L. Schlim* 1002 (type coll.; U. S. Nat. Herb., no. 1,628,290).

The rather ample material of *R. pachymorpha* in the U. S. National Herbarium, obtained in exchange from the Brussels Botanical Garden, is for the most part broken up into separate branches or small groups of branches, but enough remains to show that the plant must have had essentially the same habit as *R. seifrizii*. The longest piece, consisting of a main branch continued by a subterminal erect lateral branch, is 5 cm long. Weddell described the plant as "jaune obscur," so that it was no doubt originally of essentially the

[6] Río Hacha is a town on the coast of Colombia about 40 miles east of Dibulla. The locality where Schlim's specimens of *R. pachymorpha* were collected must have been in the same general region as that where Seifriz found *R. seifrizii*.

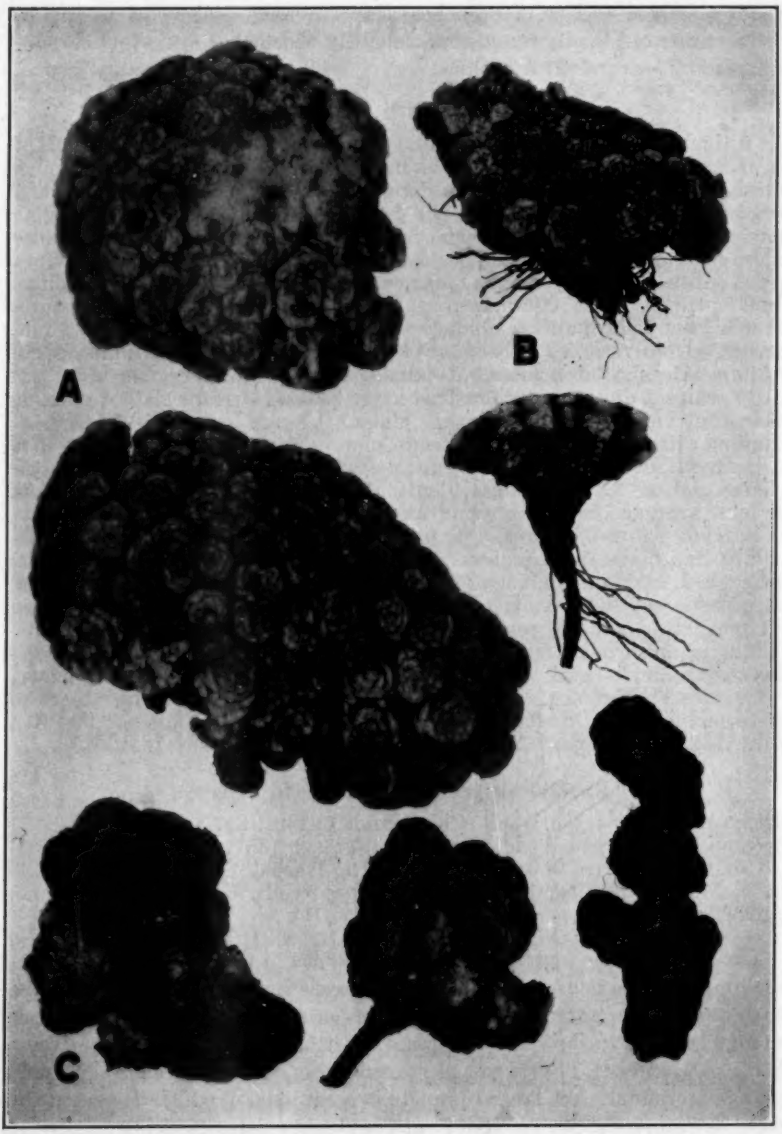


Fig. 2.—*A, Raouliopsis seifrizii* (two specimens), type; *B, Raoulia eximia* Hook. f., the upper figure from *Cockayne* 7048, the lower from *A. W. Anderson* 241, both from New Zealand and in the herbarium of the Arnold Arboretum; *C, Raouliopsis pachymorpha* (three specimens), type collection. All natural size.

same fulvous color as *R. seifrizii*, but with the lapse of more than eighty years the pubescence has become deep brown or even in places blackish. Many of the branches bear clusters of heads at their apices, the barely exposed tips of the phyllaries being in some cases narrow, whitish, and scarious, in others (where weathered ?) brown and more chartaceous, but, like Weddell, I have been unable to discover any corollas. The few achenes examined, either from the heads or caught in the pubescence, are evidently from the pistillate flowers. The achenes are glabrous, slender, 0.9 mm long, and the pappus consists of about 16 slender whitish bristles about 2.2 mm long, moderately hispidulous except toward the essentially naked base, not thickened at apex, connate at base into a ring about 0.1 mm long, and deciduous as a whole.

This species was published by Weddell as *Oligandra pachymorpha* under the heading "Oligandrae species dubia," with the synonym *"Celaena pachymorpha* Wedd., mscr." Weddell was unable to find any flowers on the specimens, but did find some achenes which he ascribed to the pistillate flowers. He described the achenes as glabrous and the pappus bristles as a little thickened above and fasciculate-connate at base. His failure to discover any trace of staminate or hermaphrodite flowers led him to suspect that the plant might be dioecious. At the close of his discussion, he remarked: "A vrai dire, cette plante est presque intermédiaire entre les genres *Oligandra* et *Merope*, et si, plus tard, on juge utile d'en faire le type d'un groupe distinct, on pourra, si l'on veut, donner à celui-ci, le nom d'une autre pléiade, et l'appeler *Celaena*."

Although the close similarity in habit between this species and *R. seifrizii* leaves little doubt of the propriety of referring both to the same genus, the adoption of the generic name suggested by Weddell has not seemed either necessary or desirable. Weddell's name is not supported by a generic description, and comes in the category of "provisional" names especially indicated as invalid in the amendments to the International Rules of Botanical Nomenclature adopted at Amsterdam in 1935. As the floral characters on which the genus rests are drawn solely from *R. seifrizii*, that species must be taken as type of the new genus, and it would be unwise to resuscitate for this a lapsed generic name originally based on another species which might later, when its floral characters become known, prove to belong to a generically different group.

BOTANY.—*The Carpet grasses.* AGNES CHASE,[1] Bureau of Plant Industry.

Carpet grass, *Axonopus compressus* (Swartz) Beauv., has always been a puzzling complex. The type from Jamaica, collected by Swartz and described by him as *Milium compressum* has not been located but the original description (Prodr. 24. 1788) and the later amplified description (Fl. Ind. Occ. 1: 183. 1797) leave no doubt that the name applies to the broad-leaved form with glume and sterile lemma pointed beyond the fruit, common in the West Indies and Brazil. In the herbarium of the Königliches Botanisches Museum at Munich is a specimen labeled, but not [?] in Swartz's script, "*Milium compressum* Sw., Jamaica, O. Swartz." This, which is probably part of the type collection, is the typical West Indian form with broad blades and spikelets with glume and sterile lemma extending well beyond the fruit.

Of the 17 names referred as synonyms to *Axonopus compressus* in Hitchcock's Manual of Grasses of the United States (page 804) the type specimen has been examined of all but two, *Milium compressum* Swartz and *Paspalum laticulmum* Spreng., the first from Jamaica. A specimen from Jamaica collected by Swartz was examined in the herbarium at Munich. Sprengel's description of *P. laticulmum* points to *Axonopus compressus*, and he cites *Milium compressum* Swartz as a synonym. All the types are the typical form of the American tropics with broad blades often slightly plicate, broad-leaved coarse stolons, and spikelets 2.2 to 3 mm long, the glume and sterile lemma extending beyond the fruit. In the United States this form is known only from Florida and Louisiana. The narrow-leaved form with glume and sterile lemma not or scarcely pointed beyond the fruit, common in the Southern States, rare in Western Cuba and southern Mexico, and infrequent in Central America, has not been described as a distinct species.

The difference from true *Axonopus compressus* is slight and there are intergrades, but on the whole specimens may be segregated with relatively few intermediates. The late Professor C. V. Piper was at one time positive that the narrow-leaved form was distinct, at first declaring it was not stoloniferous. But the writer showed him short arching stolons on some of the specimens he collected. As a whole this form is less commonly stoloniferous than is true *A. compressus*, but sometimes develops extensive stolons. Field notes by the writer on

[1] Received January 21, 1938.

narrow-leaved plants in the vicinity of Lake Charles, Louisiana, state that sterile plants form a carpet in woods of pine, oak, Liquidamber, and hickory, the flowering culms being relatively few. The specimens from this colony are tufted, with short rhizomes but no stolons.

The two forms have been recognized as distinct by various authors, the broad-leaved one generally under the name *Paspalum platycaulon* Poir. or *Anastrophus platycaulis* (Poir.) Nash, the narrow-leaved under the name *Paspalum compressum* (Swartz) Rasp. But Swartz's species is undoubtedly the same broad-leaved form as Poiret's type from Puerto Rico.

Carpet grass is esteemed as a good pasture grass from the southern Coastal Plain to Texas. In a paper on Carpet Grass by C. V. Piper and Lyman Carrier (Farmers' Bulletin 1130, U. S. Dept. Agr. pp. 1–12. 1920) it is said to be introduced into this country. The map (page 3), showing distribution from North Carolina to Texas, indicates that both forms of carpet grass are included, since the broad-leaved is known only from Florida and Louisiana. The illustration (page 5) represents the narrow-leaved form. This form is undoubtedly native, the center of distribution apparently being the Gulf Coast from Florida to Louisiana. It, like the wide-leaved form, is introduced in the tropical and subtropical regions of Asia, Africa, and Australia. The broad-leaved form is the only one known from the West Indies, except from western Cuba. It may possibly have been introduced into the Gulf States but more probably it is native though less widespread than the narrow-leaved form in the United States. It is the common form of carpet grass from Mexico to Paraguay.

No distinction in forage value seems to be made between the two forms in this country, but Dr. J. N. Whittet, agrostologist of the Department of Agriculture, Sydney, New South Wales, on a recent visit to the Office of Grass Investigations, stated that in Australia the narrow-leaved form is regarded as a pest, invading pastures of *Paspalum dilatatum* Poir. and taking possession of them, since the animals graze the paspalum and leave the carpet grass to go to seed. It is not, as might be supposed, a case of mistaken identity, because specimens of both forms from Australia are in the National Herbarium and Dr. Whittet readily recognized them. Australia produces seed of carpet grass for export, shipping it even to the United States, but, Dr. Whittet says, this is the only country that does not object to the intermixture of seed of the narrow-leaved form. The Economic Index kept by the Office of Grass Investigations contains numerous notes on carpet grass from various tropical and subtropical regions,

most of them favorable, such as "valuable, especially on poor lands," and "one of the best pasture grasses for the tropics." But in the Agricultural Gazette, New South Wales (**47**: 555. 1936), is a note on "narrow-leaved carpet grass" to the effect that it is spreading rapidly, grows well in poor soil, but tends "to invade *Paspalum dilatatum* pastures on better soil," and in the Queensland Agricultural Journal (**43**: 503. 1935) a note states that it "invades paspalum pasture and if it gets a good hold may ruin the pasture." It seems probable that the narrow-leaved carpet grass may be only less palatable than *Paspalum dilatatum*, that in regions where the paspalum is wanting or scarce, animals readily graze the narrow-leaved as well as the broad-leaved carpet grass.

Mr. Mason A. Hein, Agronomist of the Division of Forage Crops and Diseases, kindly sent inquiries as to palatability of the two forms of carpet grass to field men in the Division, and their replies confirm this opinion.

Since *Axonopus compressus* in this country is only found in Florida and southern Louisiana and is the common form in the tropics, whereas the narrow-leaved form ranges from North Carolina to Arkansas, it would appear that the latter is more winter hardy than is *A. compressus*. All factors considered, it seems better to recognize the narrow-leaved form as a distinct species.

Axonopus affinis sp. nov.

Ab *Axonopo compresso* differt: culmis et stolonibus gracilioribus, laminis angustioribus; spiculis brevioribus, 2 mm longis, obtusis vel subacutis.

Plants more tufted than in *A. compressus*, sometimes forming dense mats with short rhizomes, the flowering culms in such colonies relatively few; stolons slender, apparently mostly developing after the flowering of the primary culms, at first arching, sometimes creeping as much as 30 cm, the internodes short, and the blades not, as in *A. compressus*, conspicuously shorter than the culm blades; culms erect to geniculate-ascending, on the average more slender than in *A. compressus*, commonly 25 to 35 cm tall, rarely to 75 cm, the nodes glabrous (often bearded in *A. compressus*); sheaths compressed, on the average narrower than in *A. compressus;* blades flat or folded in drying, 2 to 4, rarely to 5 or 6 mm wide, mostly 5 to 15 cm long, rarely to 28 cm long, the apex sometimes splitting; peduncles very slender, 1 to 3 from the uppermost sheath, finally elongate; racemes 2 to 4, ascending, 2 to 10 (mostly 3 to 7) cm long; spikelets oblong-elliptic, rather more plump than in *A. compressus*, sometimes purple-tinged, 2 mm long, 0.8–0.9 mm wide, blunt or abruptly subacute, the glume and sterile lemma equal, covering the fruit or slightly pointed beyond it, 4-nerved, the midnerves suppressed, very sparsely silky-pilose at base and summit and sometimes in a line along the nerves; fruit pale, 1.7 to 1.8 mm long, blunt.

Type in the U. S. National Herbarium, no. 928710, collected "in low moist ground, Waynesboro, Mississippi, October 2, 1896, by Thos. H. Kearney, Jr. Much grazed by cattle."

Intermediate specimens are found with blades to 7 mm wide and spikelets 2.2 to 2.3 mm long, slightly pointed (*Combs* 414 and *Curtiss* 5879 in part, both from Quincy, Florida). Others with the habit of *A. compressus*, with pubescent nodes and short broad stolon blades, have spikelets 2 to 2.2 mm long but with the glume and sterile lemma pointed beyond the exceptionally short fruit (*Combs* 1324, Bradenton, and *Curtiss* 6638, Mabel, both Florida).

Low commonly moist, often sandy meadows, open woods, old fields, pastures and waste places, sometimes forming a turf, North Carolina to Florida and west to Arkansas and Texas. "Forms bulk of native pastures in open woods of Red River valley, Louisiana" C. R. Ball (no. 115). Also in western Cuba, southern Mexico.

The following specimens are in the U. S. National Herbarium:

NORTH CAROLINA: Wilmington, *Hitchcock* in 1905.

GEORGIA: Union, *Harper* 1086. Savannah, *Kearney* 197.

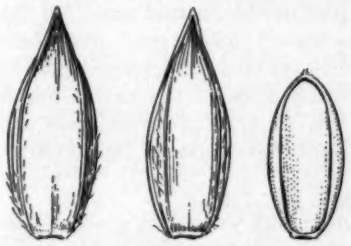


Fig. 1.—*Axonopus compressus*. Two views of spikelet, and fruit, ×10. (Type of *Paspalum tristachyon* Lam.)

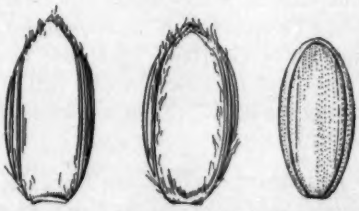


Fig. 2.—*Axonopus affinis*. Two views of spikelet, and fruit, ×10. (Type.)

FLORIDA: Avondale, *Combs* 494; Pensacola, *Combs* 517; Apalachicola, *Kearney* 111; Tallahassee, *Combs* 362, 363; *Kearney* 87; Madison, *Combs* 265, 244; Jefferson County, *Hitchcock* 2462, 2463; Monticello, *Combs* 313; De Funiak Springs, *Combs* 450; Baldwin, *Combs* 51; Jacksonville, *Combs* 1; *Curtiss* 3565, 4023, 5077, 5589, *Hitchcock* in 1900 and 1903; Duval County, *Fredholm* 5255; Quincy, *Curtiss* 5879; Chipley, *Combs* 544; Suwannee County, *Hitchcock* 2518; Lake City, *Combs* 78; *Combs & Rolfs* 109, 135, 155, 176, 181; *Hitchcock* 2461; *Rolfs* 981; Gainesville, *Combs* 733; Waldo, *Combs* 694; Ellzey, *Combs* 830; Titusville, *Chase* 3969; Sanford, *Hitchcock* 783; Eustis, *Nash* 1219; Hillsborough County, *Fredholm* 6379; Fort Meade, *McFarlin* 3724; Winter Haven, *McFarlin* 5760; Lakeland, *Hitchcock* 831; Bartow, *Combs* 1243; Bradenton, *Combs* 1332; Myers, *Hitchcock* 502, 503; Palmetto, *Tracy* 7047; Immokalee, *Swallen* 5313; Alva, *Hitchcock* in 1900.

ALABAMA: Tuskegee, *Carver* 37; Selma, *Kearney* 6; Spring Hill, *Bush* 201, 203; Tuscaloosa, *Mohr* 17.

MISSISSIPPI: Nicholson, *Kearney* 356; Biloxi, *Chase* 4333; *Ricker* 862; *Swallen* 1937; *Tracy* 3862; Ocean Springs, *Seymour* 18; *Tracy* 72, 6506.

ARKANSAS: Texarkana, *Eggert* 138; *Letterman* in 1894; Arkansas County, *Adair* 3368.

LOUISIANA: Royville, *Ball* 11. Coushatta, *Ball* 115; Shreveport, *Hitchcock* in 1903; Calhoun, *Ball* 55; Oberlin, *Ball* 224; Lake Charles, *Chase* 6100, 6109; *Hitchcock* 1121; Baton Rouge, *Billings* 18; Covington,

Arsène 11257, 11278, 12223; Pointe-a-la-Hache, *Langlois* 24, 149; Houma, *Wurzlow* in 1913, Avery Island, *Hitchcock* 19835.

TEXAS: Houston, *Bebb* 1247, 1264; *Hall* 813; *Ravenel* in 1869; Waller, *Hitchcock* 1218; Columbia, *Bush* 285; Beaumont, *Plank* 23, 28; Gonzales County, *Bogusch* 1302; Bay City, *Silveus* 901; Tom Green Co., Tweedy in 1880.

MEXICO: Jalapa, *Hitchcock* 6588; Minatitlan, *J. G. Smith* 574.

GUATEMALA: Cobán, *Türckheim* 1253.

EL SALVADOR: La Union, *Hitchcock* 8783½.

CUBA: Habana, *Léon* 298; Herradura, *Ekman* 10786; *Hitchcock* 486; Without locality, *Wright* 3850.

HAWAII: Kona (Oahu), *Hitchcock* 19699.

ASIA: Malay Peninsula, Singapore Botanic Garden, *Furtado* 25877.

AUSTRALIA: "North Coast districts, naturalized and common in New South Wales," *Whittet* B in 1930.

This species forms much the greater part of the "carpet grass" of the Southeastern States where it is esteemed as a good pasture grass, and where it may be established "in open forests, or cut-over land, without going to the expense of clearing. . . . Under close grazing most of the native bunch grasses will be killed by the end of the first season and carpet grass will occupy the land." (Piper & Carrier, U. S. Dept. Agr. Farmers' Bull. 1130: 8. 1920).

Paspalum conjugatum Berg., a common but worthless grass of the tropics and subtropics, has sometimes been confused with *Axonopus compressus*, which it resembles. Reports of forage value of *Paspalum conjugatum* (under several local names including "sour grass" in the British West Indies, "Mission grass" in Queensland) are almost certainly based on mistaking *A. compressus* for *P. conjugatum*. The two have much the same habit and often grow together. In Matto Grosso, Brazil, the writer examined native pasture of *A. compressus* and *P. conjugatum* where cattle were grazing. The *Axonopus* was closely grazed while the *Paspalum* growing with it was left untouched.

ZOOLOGY.—*North American monogenetic trematodes. II. The familes Monocotylidae, Microbothriidae, Acanthocotylidae and Udonellidae (Capsaloidea).*[1] EMMETT W. PRICE. U. S. Bureau of Animal Industry.

Family MICROBOTHRIIDAE Price, 1936

Synonyms.—Dermophagidae MacCallum, 1926; Labontidae MacCallum, 1927.

Diagnosis.—Anterior haptors present or absent; when present, in form of sucker-like structures. Posterior haptor small, without septa or hooks. Eyes usually absent. Intestinal tract consisting of 2 branches, with or without lateral diverticula. Genital apertures close together or opening into a common genital sinus. Cirrus cuticularized, or muscular with a heavily cuticularized ejaculatory duct. Vagina single or double.

Type genus.—*Microbothrium* Olsson, 1869.

The family names Dermophagidae MacCallum (1926) and Labontidae MacCallum (1927) are unavailable, since the genus *Dermophagus* MacCallum was preoccupied, and the genus *Labontes* MacCallum, which was proposed to replace *Dermophagus*, is shown later on in this paper to be a synonym of *Microbothrium* Olsson.

KEY TO SUBFAMILIES OF MICROBOTHRIIDAE

One or two testes ..... MICROBOTHRIINAE Price
Numerous testes ..... PSEUDOCOTYLINAE Monticelli

Subfamily MICROBOTHRIINAE, new name

Synonyms.—Anoplodiscinae Tagliani, 1912; Dermophaginae MacCallum, 1926; Labontinae MacCallum, 1927; Paracotylinae Southwell and Kirshner, 1937.

Diagnosis.—Anterior haptor in form of an oral sucker or of adoral pseudosuckers. Eyes present or absent. One or two testes. Vagina usually single (double in *Leptobothrium*).

Type genus.—*Microbothrium* Olsson, 1869.

KEY TO GENERA OF MICROBOTHRIINAE

1. Two testes ..... *Dermophthirius* MacCallum
   One testis 2
2. Eyes present ..... *Anoplodiscus* Sonsino
   Eyes absent 3
3. Intestinal branches without lateral dendritic diverticula ..... *Leptocotyle* Monticelli
   Intestinal branches with lateral diverticula 4
4. Vagina single ..... *Microbothrium* Olsson
   Vagina double ..... *Leptobothrium* Gallien

Genus MICROBOTHRIUM Olsson, 1869

Synonyms.—*Dermophagus* MacCallum, 1926, not Dejean, 1833; *Labontes* MacCallum, 1927; *Philura* MacCallum, 1926.

[1] Continued from Vol. 28, No. 3. THIS JOURNAL. Received February 12, 1938.

Diagnosis.—Anterior haptors in form of 2 bothria-like structures opening into oral cavity; posterior haptor an elliptical, heavily cuticularized groove. Oral aperture subterminal, groove-like; intestinal branches with lateral, dendritic diverticula. Genital aperture median. Cirrus long, muscular, with heavily cuticularized ejaculatory duct. Testis single, equatorial. Vagina single, not opening into genital atrium.

Type species.—*Microbothrium apiculatum* Olsson, 1869.

This genus at present contains only the type species. Olsson (1869) questionably assigned to this genus a form from the dorsum of "*Rajae Batidis*," which he named *Microbothrium* (?) *fragile*. This form is now generally believed to be a parasitic triclad turbellarian, possibly identical with *Microparynx parasitica* Jägerskiöld.

Microbothrium apiculatum Olsson, 1869 Figs. 1–2

Synonyms.—*Pseudocotyle apiculatum* (Olsson, 1869) Braun, 1890; *Philura orata* MacCallum, 1926; *Dermophagus squali* MacCallum, 1926.

Description.—Body elliptical, 1.7 to 3.2 mm long by 700μ to 1.6 mm wide, convex dorsally, flattened or slightly concave ventrally. Cephalic glands present. Anterior haptors in form of 2 sucker-like organs opening into mouth cavity; posterior haptor an elliptical opening, 150 to 225μ long, at posterior end of body, unarmed, its cavity lined with thick cuticle. Oral aperture slit-like, subterminal; prepharynx relatively long; pharynx ovoid to piriform, 190 to 300μ long by 200 to 266μ wide; esophagus very short; intestinal tract consisting of 2 relatively slender branches with a number of lateral, more or less dendritic diverticula. Nervous system not observed. Genital aperture median, about one-third of body length from anterior end. Cirrus long, muscular, lying in a rather spacious genital sinus; the ejaculatory duct, which passes through the center of the cirrus, strongly cuticularized and expanded proximally to form a more or less globular ejaculatory bulb. Vas deferens relatively large and expanded distally; seminal vesicle globular, about 80 to 170μ in diameter, at level of ovary. Testis circular in outline, with smooth or indented margins, 340 to 510μ in diameter, in equatorial zone. Ovary globular, 85 to 170μ in diameter, immediately pretesticular, to right of median line. Vitellaria extending from level of pharynx to within about 500μ from posterior end of body, meeting in median line posterior to testis. Vagina strongly muscular, convoluted, its proximal end expanded and forming a seminal receptacle, 40 to 115μ in diameter, between ovary and seminal vesicle; vaginal opening at level of genital aperture near left intestinal branch. Ootype piriform, about 190μ wide, surrounded by unicellular glands. Egg oval, about 130μ long by 80μ wide, with relatively short polar process.

Hosts.—*Squalus acanthias* Linn., and *Carcharias commersonii* (Blainville).

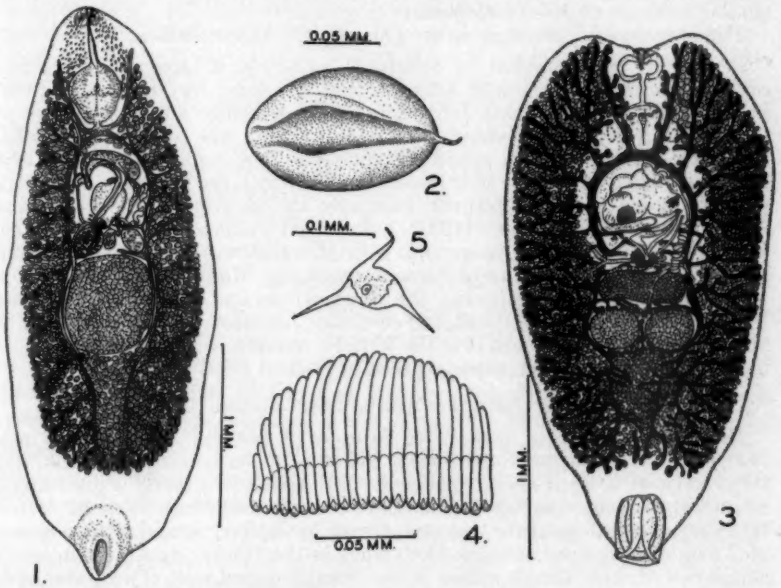
Location.—Skin.

Distribution.—United States (Woods Hole, Mass.) and Canada.

Specimens.—U.S.N.M. Helm. Coll. Nos. 35684 (cotypes of *Dermophagus squali*), 35685 (cotypes of *Philura orata*) and 35686.

Microbothrium apiculatum was first described by Olsson (1869) from specimens collected from the dorsum of "*Acanthiae vulgaris*" taken in the Skagerrak. The description was not very complete as to details of the genital systems; these details were supplied later by Saint-Remy (1891). The first

report of this species in North America is that by Stafford (1904) who listed *Pseudocotyle apiculatum* (=*Microbothrium apiculatum*) from *Squalus acanthias*, the specimens having been collected at the Canadian Marine Biological Station. MacCallum (1926) described as *Philura orata* n. g., n. sp., an ectoparasitic fluke from the skin of *"Carcharhinus commersonii"* collected at Woods Hole, Mass., and later in the same year (1926) he described as *Dermophagus squali*, n. g., n. sp., a somewhat similar fluke from *Squalus acanthias* also collected at Woods Hole, Mass. A study of these forms reveals



Figs. 1–2.—*Microbothrium apiculatum*. 1, complete worm, ventral view; 2, egg. Figs. 3–5.—*Dermophthirius carcharhini*. 3, complete worm, ventral view; 4, cirrus spines; 5, egg.

that both *Philura orata* and *Dermophagus squali* are identical with *Microbothrium apiculatum* Olsson. The specimens are not so large as the maximum size given by Olsson, Stafford or MacCallum, but aside from this they check in every essential with the description as given by Olsson and by Saint-Remy.

Genus LEPTOBOTHRIUM Gallien, 1937

Synonym.—*Pseudobothrium* Gallien, 1937, nec Guiart, 1935.

Diagnosis.—Oral aperture subterminal, surrounded by a pseudosucker. Posterior haptor small, unarmed. Intestine with lateral non-dendritic diverticula, not uniting posteriorly. Eyes absent. Testis single; cirrus simple. Ovary small, pretesticular. Vagina present, bifurcating to form 2 branches both opening into genital atrium. Other characters similar to those of *Microbothrium*.

Type species.—Leptobothrium pristiuri (Gallien, 1937) Gallien, 1937.

The type and only species of this genus was described by Gallien (1937), from specimens collected from the skin of *Pristiurus melanostomus* taken in European waters.

Genus Leptocotyle Monticelli, 1905

Synonym.—Paracotyle Johnstone, 1911.

Diagnosis.—Anterior haptor in form of a weakly developed oral sucker. Intestinal branches without lateral dendritic diverticula. Other characters similar to those of *Microbothrium*.

Type species.—Leptocotyle minor (Monticelli, 1888) Gallien, 1937.

Leptocotyle was proposed by Monticelli (1905) as a subgenus of *Pseudocotyle* to contain *Pseudocotyle minor*, a species named by Monticelli (1888) but not described until 1890. Johnstone (1911) described a form which seems to be identical with *P. minor* Monticelli, naming the species *Paracotyle caniculae*. Tagliani (1912) raised the subgenus *Leptocotyle* to the rank of a genus but failed to include in it the species for which the subgenus was originally proposed; he did, however, recognize the identity of *Paracotyle* and *Leptocotyle*. Recently Jones (1933) redescribed Johnstone's *Paracotyle caniculae* and considered it congeneric with *Microbothrium apiculatum* Olsson; he apparently did not know of *Pseudocotyle minor* Monticelli, as no mention of it was made. In comparing the descriptions and figures of *P. minor* Monticelli with those of *Paracotyle caniculae* Johnstone, there appear to be no essential differences and it is the writer's opinion that the two forms are identical; this conclusion supports that of Gallien (1937).

Genus Dermophthirius MacCallum, 1926

Diagnosis.—Anterior haptors in form of 2 bothria opening into oral cavity; posterior haptor consisting of 2 clamp-like cuticular jaws resembling the valves of a clam shell, unarmed. Oral aperture slightly subterminal; intestinal branches similar to but more conspicuous than those of *Microbothrium*. Genital aperture sinistral. Cirrus muscular, armed with a group of 2 overlapping rows of stave-like spines in the thicker ventral wall and a single row of short simple spines in the thinner dorsal wall. Two testes, side by side, postequatorial. Vagina single.

Type species.—Dermophthirius carcharhini MacCallum, 1926.

Dermophthirius carcharhini MacCallum, 1926 Figs. 3–5

Description.—Body elongate, ovoid, 1.9 to 2.9 mm long by 850μ to 1.5 mm wide at level of pharynx. Anterior haptor in form of bothria opening into oral cavity; posterior haptor clam shell-like, about 340μ long, strongly cuticular, its inner surface roughened but without hooks. The exact shape and function of this haptor could not be ascertained in the specimens available owing to the large amount of detritus caught in its jaws. Oral aperture slightly subterminal; prepharynx moderately long and spacious; pharynx piriform, widest anteriorly, 190 to 245μ long by 95 to 228μ wide, projecting into a widened prepharynx; esophagus absent; intestinal branches with long lateral and shorter median dendritic diverticula. Nervous system not ascertainable; eyes absent. Excretory apertures dorsal, at level of pharynx. Genital aperture to left of median line and about midway between base of pharynx and anterior margin of ovary. Genital sinus spacious. Cirrus muscular and of peculiar shape; ventral wall greatly thickened and bearing

on its inner surface 2 rows of stave-like spines, the innermost row of about 25 spines 19 to 40μ long and outermost row of about 25 spines 25 to 70μ long; dorsal wall thinner and bearing a single row of about 28 straight spines having a maximum length of about 20μ. Vas deferens convoluted proximally, widening and forming a seminal vesicle slightly anterior to level of cirrus, then passing into a long, conspicuous, convoluted prostatic portion lying immediately anterior to cirrus; prostatic portion lined with high columnar epithelium. Testes round, 150 to 285μ in diameter, side by side, immediately postovarial. Ovary elongate transversely, 90 to 190μ long by 230 to 455μ wide, median, slightly postequatorial. Vitellaria consisting of relatively large follicles occupying greater part of body, except that occupied by genital organs, extending from anterior end of body to posterior limits of intestinal diverticula. Vagina slender, opening near genital aperture. Ootype median, surrounded at its base by unicellular glands; metraterm short and thin walled. Egg tripolar, about 76μ long (excluding polar prolongations).

Host.—*Carcharias commersonii* (Blainville).

Location.—Olfactory organs and skin of back.

Distribution.—United States (Woods Hole, Mass.).

Specimens.—U.S.N.M. Helm. Coll. Nos. 35687 (cotypes), 35688, and 36644.

This species has been described very accurately by MacCallum (1926) except for a few details. The common genital aperture is not median but somewhat sinistral; the vaginal aperture is also somewhat sinistral. The posterior haptor is not in the form of a shallow groove, as originally figured and described, but consists of a pair of jaw-like cuticularized structures which have somewhat the appearance of the valves of a clam shell. In most of the specimens the posterior haptor has been torn off and the description of the posterior sucker or haptor as given by MacCallum was obviously from one of these mutilated specimens. The exact detail of the haptor could not be made out because of the mass of detritus clamped between the jaws; it must possess enormous powers of attachment as it had been torn from all but 3 of about 20 specimens examined.

Genus ANOPLODISCUS Sonsino, 1890

Diagnosis.—Anterior haptors in form of a pair of pseudosuckers situated at anterior end of body. Posterior haptor cup-like, unarmed. Eyes present. Cirrus cuticularized, with accessory piece. Testis single, preequatorial. Ovary pretesticular. Vagina present.

Type species.—*Anoplodiscus richiardii* Sonsino, 1890.

The type species of *Anoplodiscus*, *A. richiardii*, was originally described by Sonsino (1890) from the gills of *Pagrus orphus* from the Mediterranean, and was subsequently redescribed by Monticelli (1905); neither description is adequate. The only other species so far included in this genus is *A. australis* which was described by Johnston (1930) from specimens collected from the fin of *Sparus australis* taken at Sydney Harbour, Australia.

The systematic position of the genus *Anoplodiscus* is not well established. Monticelli placed it in the Anisocotylinae Monticelli, 1903—a subfamily

without a corresponding genus and consequently invalid—and later Tagliani (1912) erected for it the subfamily Anoplodiscinae, elevating Monticelli's invalid Anisocotylinae to the status of an invalid family Anisocotylidae. Johnston and Tiegs (1922) consider *Anoplodiscus* as possibly belonging to the Calceostomidae, subfamily Dionchinae, while Fuhrmann (1928) and Gallien (1937) place it in the Pseudocotylinae. The present writer has, without prejudice, included *Anoplodiscus* in the Microbothriinae, mainly because the general organization and the lack of haptoral hooks suggest relationship with such genera as *Microbothrium*, *Leptocotyle* and *Leptobothrium*. On the other hand, the presence in *Anoplodiscus* of eyes and a cirrus with accessory piece suggests affinities with genera of the Gyrodactyloidea. It is possible that a restudy of the species of *Anoplodiscus* may show the haptor to be armed with minute hooks in which case it should be transferred to the family Calceostomatidae (Gyrodactyloidea).

Subfamily PSEUDOCOTYLINAE Monticelli, 1903

Diagnosis.—Anterior haptors absent; posterior haptor small, suckerlike, unarmed. Eyes absent. Genital apertures close together, median. Testes numerous. Vagina double, not opening into genital atrium.

Type genus.—*Pseudocotyle* Beneden and Hesse, 1865.

Genus PSEUDOCOTYLE Beneden and Hesse, 1865

Diagnosis.—With characters of subfamily.

Type species.—*Pseudocotyle squatinae* Beneden and Hesse, 1865.

The genus *Pseudocotyle* contains only the type species; it has not been reported from North America.

Family ACANTHOCOTYLIDAE Price, 1936

Synonym.—Anisocotylidae Tagliani, 1912, in part.

Diagnosis.—Anterior haptors in form of retractile suckers or of weakly developed suckers surrounded by openings of cephalic gland ducts. Posterior haptor small, bearing usually 1 pair of centrally placed hooks and 14 marginal hooklets; sometimes with large disc-like pseudo-haptor bearing rows of spines, or with radial septa. Genital apertures separate; male aperture median or sublateral; female aperture lateral and marginal. Vagina (?). Testis single or multiple.

Type genus.—*Acanthocotyle* Monticelli, 1888.

The family Acanthocotylidae is erected to include 3 genera, viz., *Acanthocotyle* Monticelli, *Lophocotyle* Braun and *Enoplocotyle* Tagliani. The first two of these genera are included in the subfamily Acanthocotylinae Monticelli and the third in the subfamily Enoplocotylinae Tagliani.

Recent writers, including Johnston and Tiegs (1922) and Fuhrmann (1928), are not in agreement as to the affinities of these genera. Johnston and Tiegs place the genera *Acanthocotyle* and *Lophocotyle* in the Acanthocotylinae which they append to the superfamily Gyrodactyloidea; they do not mention the genus *Enoplocotyle*. Fuhrmann apparently does not recognize either the subfamily Acanthocotylinae or Enoplocotylinae, placing *Acanthocotyle*, *Lophocotyle* and *Enoplocotyle* in the family Monocotylidae.

The present writer regards the affinities of *Acanthocotyle*, *Lophocotyle* and *Enoplocotyle* such as to warrant the erection for them of a family separate from the Monocotylidae. In these genera the male and female genital apertures are relatively far removed, while in the Monocotylidae the male and female apertures are close together. Furthermore, in both *Acanthocotyle* and *Enoplocotyle*, and possibly also in *Lophocotyle*, the cephalic gland ducts open around the margins of the anterior sucker-like haptors; this is not the case in the Monocotylidae.

KEY TO SUBFAMILIES OF ACANTHOCOTYLIDAE

Posterior haptor very small, situated at margin of large disc-like pseudohaptor bearing radial rows of spines, or with muscular septa.....
.....ACANTHOCOTYLINAE Monticelli
Posterior haptor relatively large, without pseudohaptor.....
.....ENOPLOCOTYLINAE Tagliani

Subfamily ACANTHOCOTYLINAE Monticelli, 1903

Diagnosis.—Anterior haptors in form of 2 retractile suckers, or of corresponding concentrations of cephalic gland ducts. Posterior haptor very small, at margin of large disc-like pseudohaptor. Testes numerous.
Type genus.—*Acanthocotyle* Monticelli, 1888.

The posterior adhesive organs in members of the Acanthocotylinae differ from those occurring in other representatives of the Capsaloidea in consisting of a large sucker-like structure provided with a small armed disc situated at its posterior margin. The large sucker bears on its ventral surface either radial ridges (*Lophocotyle*) or radial rows of spines (*Acanthocotyle*); this structure has been termed a pseudohaptor (Price, 1937). The small disc is the true haptor and is undoubtedly homologous with the haptor of gyrodactylids, dactylogyrids, monocotylids and capsalids, since it is armed with hooks which are distributed as in the above forms. The spines of the pseudohaptor have usually been referred to as hooks, but since they are not provided with muscular attachments they can not be regarded as hooks in the same sense as those of the true haptor. In the present paper, as well as in others by the writer, the term *hook* is reserved for those cuticularized or chitinized structures which are freely movable due to muscular action, and the term *spine* is used for similar structures not provided with muscles; we may have, therefore, spine-like hooks as well as hook-like spines.

KEY TO GENERA OF ACANTHOCOTYLINAE

Pseudohaptor with radial rows of spines.....*Acanthocotyle* Monticelli
Pseudohaptor without radial rows of spines.....*Lophocotyle* Braun

Genus ACANTHOCOTYLE Monticelli, 1888

Diagnosis.—Anterior haptors in form of 2 retractile suckers; cephalic glands present, opening around margins of suckers. Pseudohaptor large, bearing radiating rows of irregularly shaped spines. Intestinal branches without lateral diverticula.
Type species.—*Acanthocotyle lobianchi* Monticelli, 1888.

The genus *Acanthocotyle* contains at present 9 apparently valid species as follows: *A. branchialis* Willem (1906), *A. elegans* Monticelli (1890), *A. lobianchi* Monticelli (1888), *A. monticellii*[2] Scott (1902), *A. oligoterus* Monticelli (1899), *A. pacifica* Guberlet (1937), *A. pugetensis* Guberlet (1937), *A. verrilli* Goto (1899), and *A. williamsi*, n. sp.; all except the last four of these species occur on European rays and are not known to occur on North American hosts.

Acanthocotyle williamsi, n. sp. Fig. 6–9

Description.—Body linguiform, flat, 3.7 to 4.4 mm long by 1.3 to 1.6 mm wide. Anterior sucker-like haptors 150μ long by 110μ wide, retracted into groove-like depressions. Cephalic glands present, opening around margins of haptors as in other species of the genus. Pseudohaptor disc-like, 1.2 to 1.3 mm in diameter, its ventral surface provided with 20 rows (21 rows in 1 specimen) of strong spines, the 2 most posterior rows with 3 to 6 spines each and the other rows with 6 to 10 each; outermost spines longest, truncate at tips. Posterior haptor 55 to 65μ in diameter, situated at distal margin of pseudohaptor, armed with 16 hooks, 2 centrals and 14 marginals, each about 18 to 20μ long. Oral aperture ventral, median, about 240μ from anterior end of body. Pharynx globular, 320 to 400μ in diameter. Esophagus very short; intestinal branches simple, without diverticula. Brain anterodorsal of oral aperture; no eyes; one pair of sensory papillae near anterior margin, immediately median to haptors. Excretory vesicles anterior to vitellaria, opening dorsally near lateral margins of body. Male genital aperture median or slightly submedian, immediately posterior to base of pharynx. Cirrus pouch relatively large, curved, containing an internal seminal vesicle and a relatively short cirrus; vas deferens enlarged and constricted to form 2 external seminal vesicles, the most posterior being rosette-shaped. Paired prostatic vesicles present, one on each side of cirrus pouch, extending from level of middle of anterior seminal vesicle to genital aperture; these lie entirely outside the cirrus pouch and are often voluminous. Testes 32 to 57 in number, in intercecal field posterior to ovary. Ovary globular, 270 to 320μ in diameter, median, about one-third of body length from anterior end. Vitellaria extracecal, consisting of large elongate follicles, extending from level of ovary to near posterior end of body proper. Seminal receptacle present, postero-dorsal of ovary; vagina absent. Ootype elongate, in median field, uniting with uterus by means of a short slender duct; uterus cylindrical, relatively short, opening into relatively large club-shaped muscular metraterm. Female aperture dextral, dorsal, at level of anterior part of pharynx. Egg 275μ long, exclusive of filament, by 68μ wide.

Host.—"Skate."

Location.—Skin.

Distribution.—Aleutian Islands (Salt Island).

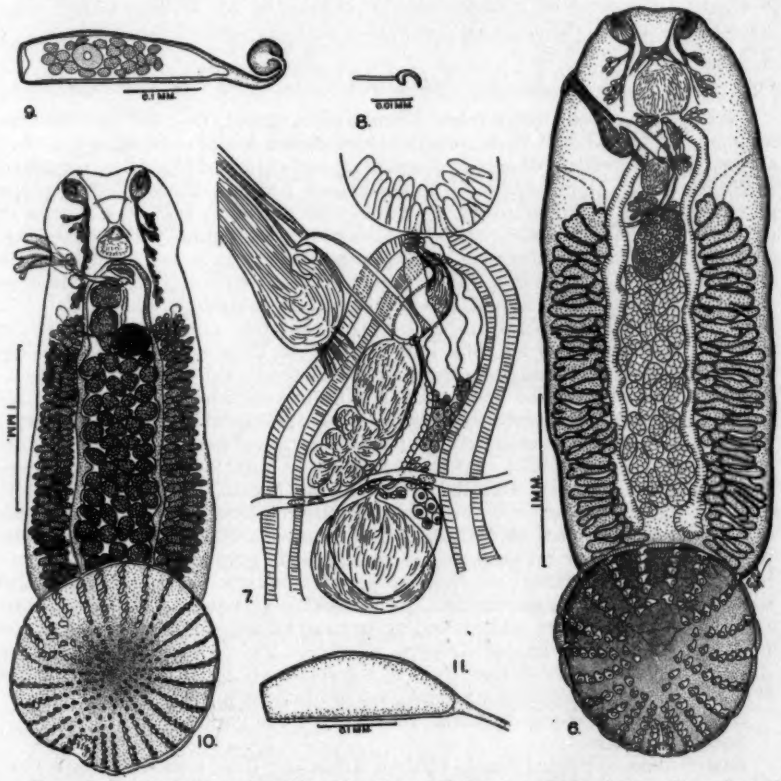
Specimens.—U.S.N.M. Helm. Coll. No. 9033 cotypes; collected July 7, 1936, by C. S. Williams, for whom the species is named.

This species appears to resemble more closely *A. branchialis* Willem than any of the other species of *Acanthocotyle*. The two species differ mainly in the number of pseudohaptoral spines, there being 7 to 8 spines in the most

[2] *Acanthocotyle concinna* Scott, 1902, appears to be a lapsus for *A. monticellii;* the name is mentioned only once and then in connection with a comparison of *A. monticellii* with other species of the genus.

posterior rows and 9 to 14 in the others in *A. branchialis*, and 3 to 6 in the most posterior rows and 6 to 10 in the others in *A. williamsi*.

A study of specimens of this and some other species of *Acanthocotyle* has convinced the writer that Monticelli (1899) was in error in interpreting parts of the male and female genital systems in species of this genus. According to Monticelli's descriptions and very elaborate figures of these systems



Figs. 6–9.—*Acanthocotyle williamsi*. 6, complete worm, ventral view; 7, male and female genital complex; 8, haptoral hook; 9, egg. Figs. 10–11.—*Acanthocotyle verrilli*. 10, complete worm, ventral view; 11, egg.

in the species described by him, there is a large cirrus sac containing a cirrus, internal seminal vesicle and a prostatic vesicle. He also described and figured a vagina extending from the seminal receptacle and opening near the male aperture. According to the present writer's observations on serial sections and toto mounts of several specimens of *A. williamsi*, as well as observations on specimens of *A. verrilli* and two species kindly supplied by Kelsaw Bonham, University of Washington, Seattle, Wash., the cirrus pouch is very delicate

and encloses only a small cirrus and a large internal seminal vesicle; the prostatic vesicles are two in number, both lying free in the parenchyma, one on each side of the cirrus pouch, and opening opposite each other in a shallow genital atrium. There is no trace of either a vaginal aperture or a vagina in any of the species studied, and it appears that what was regarded as a vagina by Monticelli was one of the prostatic vesicles. The conclusion that a vagina is absent in species of *Acanthocotyle* is supported by Willem (1906) who stated that he was unable to demonstrate this structure in specimens of *A. branchialis*.

Acanthocotyle verrilli Goto, 1899 Figs. 10–11

Description.—Body linguiform, almost rectangular, flat, 3.5 to 3.89 mm long by 1.2 to 1.3 mm wide, slightly constricted at level of pharynx. Anterior haptors in form of a pair of suckers, each about 114μ wide, retracted into groove-like depressions. Cephalic glands present, their ducts opening at margins of anterior haptors. Pseudohaptor disc-like, 1.28 to 1.36 mm in diameter, slightly concave, with 30 radial rows of irregularly shaped spines, 4 to 15 in each row, outermost spines longer than others and with truncate tips; posterior haptor about 130μ in diameter, at posterior margin of pseudohaptor, armed with 16 hooks, 2 centrals and 14 marginals, each about 30μ long. Oral opening ventral, about 340 to 425μ from anterior end of body. Pharynx piriform, 190 to 285μ long by 247 to 293μ wide; esophagus extremely short; intestinal branches with slight median diverticula, terminating near posterior end of body proper. Nervous system not completely ascertainable; brain immediately anterior to oral aperture; eyes absent; 1 pair of sensory papillae situated at anterior margin of body, 1 papilla median to each haptor. Excretory vesicles immediately anterior to vitellaria, opening dorsally near lateral margins of body. Male genital aperture submedian, about 570μ from anterior end of body; cirrus relatively short; vas deferens dilated and constricted to form 2 seminal vesicles. Paired prostate vesicles present, one opening on each side of male genital aperture. Testes about 57 in number, in interintestinal field posterior to ovary. Ovary globular, 210 to 228μ in diameter, submedian, pretesticular. Vitellaria extracecal, consisting of large follicles and extending from ovarial zone to posterior end of body proper. Vagina absent. Ootype relatively wide, extending anteriad in median line, joined by slender duct to the relatively long uterus; metraterm relatively wide. Egg 259μ long, exclusive of filament, by 80μ wide.

Hosts.—*Raja erinacea* Mitchill, *R. radiata* Donovan, and "blue fish."

Location.—Skin.

Distribution.—United States (North Atlantic). Reported from Cape Cod, Mass., by Goto (1899); from Canada by Stafford (1904); and from off the coast of Maine by Manter (1926).

Specimens.—U.S.N.M. Helm. Coll. No. 7175.

The description given here is based on 2 specimens from a "blue fish," collector unknown, which were found in the U. S. National Museum.

This species appears to be somewhat variable, as considerable difference was noted between the specimens studied by the writer and those described by Goto (1899) and by Manter (1926); these differences, however, were more or less minor, being in the number of testes and in the number of rows of spines on the pseudohaptor. Goto reported the number of testes as 37 and

Manter as 52, while in the writer's specimens there were at least 57. The number of rows of spines on the pseudohaptor was given as 34 by Goto and 32 by Manter; in the writer's specimens there were 30 rows. In spite of these differences there seems to be no reason for regarding the specimens from the 3 collections as representing different species.

Acanthocotyle pacifica Guberlet, 1937

This species was reported by Guberlet (1937) as occurring on the skin and only rarely on the gills of *Raja binoculata* Girard, *R. stellulata* Jordan and Gilbert and *R. rhina* Jordan and Gilbert from the Pacific Coast. The only character given for this species was that the pseudohaptor bears 32 or more rows of spines.

Acanthocotyle pugetensis Guberlet, 1937

This species was reported as occurring principally on the gills of the same hosts as *A. pacifica*. The pseudohaptor bears 20 rows of spines.

Genus LOPHOCOTYLE Braun, 1896

Diagnosis.—Anterior haptors in form of 2 groups of cephalic gland duct openings. Pseudohaptor similar to that of *Acanthocotyle* but with muscular radii instead of rows of spines. Intestinal branches with lateral diverticula. Male and female genital apertures apparently not so widely separated as in *Acanthocotyle;* testes numerous.

Type species.—*Lophocotyle cyclophora* Braun (1896).

The type and only species of this genus was based on 2 specimens, collected at Puerto Toro by the Hamburg Magellan-Expedition "wahrscheinlich von der Haut eines Fisches der Gattung *Notothenia.*" The specimens apparently were not in good condition as certain features of the worm were not well described. The general appearance, however, indicates a very close relationship with members of the genus *Acanthocotyle*.

Subfamily ENOPLOCOTYLINAE Tagliani, 1912

Diagnosis.—Anterior haptors in form of 2 very weakly developed suckers, with ducts of cephalic glands opening around them. Posterior haptor relatively large, with 1 pair of centrally placed hooks and 14 marginal hooklets, each of the latter located in center of an oval sucker-like depression. Testis single, immediately postovarial.

Type genus.—*Enoplocotyle* Tagliani, 1912.

Genus ENOPLOCOTYLE Tagliani, 1912

Diagnosis.—Characters of subfamily.

Type species.—*Enoplocotyle minima* Tagliani, 1912.

This genus contains only the type species; it is not known to occur in North American hosts.

Family UDONELLIDAE Taschenberg, 1879

Diagnosis.—Body elongate, cylindrical or subcylindrical; cuticula with distinct or indistinct annulations. Anterior haptors present or absent, when present, in form of 2 small suckers or sucker-like structures; cephalic glands present. Posterior haptor sucker-like, without radii, unarmed. Pharynx

well developed, protrusible. Intestine simple, sac-like, unbranched, sometimes fenestrate in testicular and ovarian zones. Genital aperture median or submarginal; cirrus absent; testis single. Ovary pretesticular, median. Egg oval or elongate piriform, with long filament at one pole.

Type genus.—*Udonella* Johnston, 1835.

Genus UDONELLA Johnston, 1835

Synonyms.—*Lintonia* Monticelli, 1904; *Calinella* Monticelli, 1910.

Diagnosis.—Anterior haptors in form of 2 small suckers or sucker-like structures; posterior haptor terminal, sucker-like, unarmed. Pharynx without hooks or spines; intestine simple, sac-like, sometimes fenestrate in ovarian and testicular zone.

Type species.—*Udonella caligorum* Johnston, 1835.

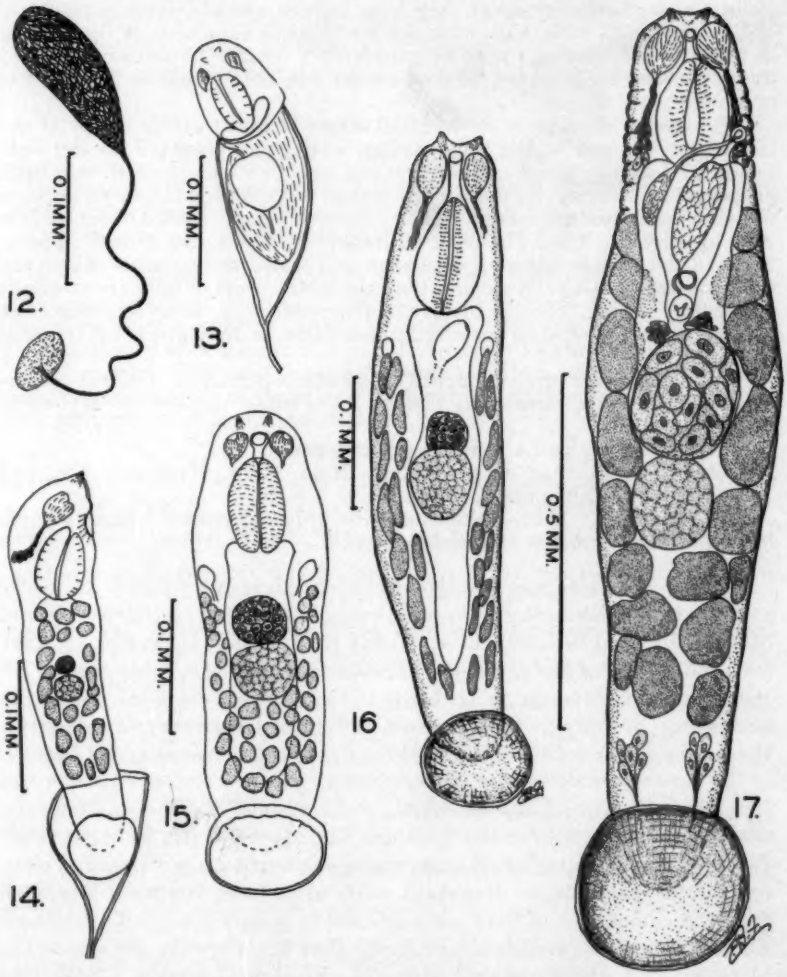
The genera *Lintonia* Monticelli (1904) and *Calinella* Monticelli (1910) are regarded as synonyms of *Udonella* Johnston, as the characters given for these genera are of no more than specific value. The type of *Lintonia, L. papillosa* (Linton), is shown further on in this paper to be the same as *Udonella socialis* Linton, and both are apparently identical with *U. caligorum* Johnston. *Calinella craneola* Monticelli shows a fenestration of the simple sac-like intestinal cecum but otherwise appears to be very similar to *U. caligorum;* this single character is not regarded as generic.

The genus *Udonella* contains at the present time the following species: *U. caligorum* Johnston, *U. craneola* (Monticelli), *U. lupi* Beneden and Hesse, *U. merlucii* Beneden and Hesse, *U. pollachii* Beneden and Hesse, *U. sciaenae* Beneden and Hesse, and *U. triglae* Beneden and Hesse. Of these species only the first two, *U. caligorum* and *U. craneola*, appear to be distinguishable; the remaining species are imperfectly described and probably not all congeneric.

Udonella caligorum Johnston, 1835 Figs. 12–17

Synonyms.—*Nitzschia papillosa* Linton, 1898; *Lintonia papillosa* (Linton, 1898) Monticelli, 1904; *Udonella socialis* Linton, 1910; *Calinella myliobati* Guberlet, 1936.

Description.—Body elongate, 1.1 to 1.36 mm long by 255μ wide at ovary, subcylindrical; cuticula of anterior end of body in mature specimens showing pseudoannulations. Anterior haptors sucker-like, retractile, about 42 to 57μ wide; cephalic glands present, their ducts leading apparently to anterior haptors. Posterior haptor sucker-like, 187 to 210μ in diameter, without septa or hooks. Caudal glands present, arranged in 2 submarginal groups near posterior end of body proper. Oral aperture subterminal, median. Pharynx oval, 150 to 152μ long by 85 to 95μ wide, apparently partially protrusible. Intestine simple, sac-like, unbranched, extending to near posterior end of body proper. Nervous system not observed; eyes absent; one pair of conspicuous sensory papillae present at anterior end of body. Excretory vesicles submarginal, at or slightly posterior to level of base of pharynx, conspicuous in small specimens. Genital aperture sinistral, submarginal, slightly anterior to level of posterior end of pharynx. Cirrus apparently absent; ejaculatory duct slender and leading from an oval seminal vesicle lying to right of anterior end of ootype. Testis single, median, 76 to 95μ in diameter, equatorial. Ovary globular, 133μ in diameter, median, pretesticular. Vitel-



Figs. 12–17.—*Udonella caligorum*. 12, egg; 13 and 14, egg hatching; 15 and 16, young forms showing different degrees of maturity; 17, adult worm.

laria consisting of few relatively large follicles, extending from slightly posterior to pharynx to a short distance anterior to posterior end of body. Vagina absent. Ootype large, vesicular, its base surrounded by unicellular glands; metraterm very short. Egg from balsam mounts elongate piriform, 133μ long by 42μ wide, with long slender filament expanded at tip to form an adhesive disc; the eggs were all considerably contracted and wrinkled and the measurements given are no doubt much less than would be those of unpreserved eggs.

Life history.—Immature forms in all stages of growth from escape of the larva from the egg to the fully mature adult were observed on the slide mount of *Udonella socialis*. These various growth stages showed very little of special significance. At the time of escape from the egg the worm appears to be virtually mature except for size; the smallest individual observed was 210μ long by 57μ wide. The most noticeable change during growth appears to be in the relative sizes of the ovary and testis; in immature stages the ovary is always distinctly smaller than the testis, while in fully grown adults the reverse is true. The life history of this species, so far as represented in the available material, is essentially the same as that given by Beneden (1858).

Hosts.—"*Argulus* sp." in mouth of *Neomaenis griseus; Caligus* sp., on *Gadus callarias* Linnaeus; and *Trebius latiturcatus*, parasite on *Myliobatis californicus* Gill.

Location.—Body and appendages of copepod.

Distribution.—United States (Woods Hole, Mass., Tortugas, Fla., and Monterey Bay, Calif.) and (?) Canada.

Specimens.—U.S.N.M. Helm. Coll. Nos. 4874 (cotypes of *Nitzschia papillosa*) and 8537 (cotypes of *Udonella socialis*).

Udonella caligorum was first reported from this country by Linton (1898) as *Nitzschia papillosa*, the description being based upon specimens collected by the late Vinal N. Edwards at Woods Hole, Mass., December 15, 1885, from the (?) gills of *Gadus callarias*. The description was very incomplete and the illustrations inadequate. Owing to the incompleteness of the description and figures, Monticelli (1904) secured the cotype specimens and redescribed the species as *Lintonia papillosa*, placing his newly created genus *Lintonia* in the family Monocotylidae. Later, Linton (1910) described as a new species, *Udonella socialis*, a form which he found on "*Argulus* sp." from the mouth of *Neomaenis griseus* at Tortugas, Fla. More recently Guberlet (1936) described *Calinella myliobati* from specimens found on a copepod, *Trebius latifurcatus*, parasitic on *Myliobatis californicus* from Monterey Bay, California. A comparison of the type specimens of *N. papillosa* (=*L. papillosa*), *U. socialis* and *C. myliobati* has shown that these species are apparently identical with the European *Udonella caligorum* Johnston (1835) from *Caligus* sp. parasitic on the halibut, *Hippoglossus vulgaris*. *U. caligorum* has also been reported by Stafford (1904) from *Caligus* sp. on *Gadus callarias* from Canada; none of the latter species was available for study.

U. caligorum seems to be quite variable as regards size, the variation in length ranging from "about 4 lines," according to Johnston (5 to 6 mm according to Beneden (1858); 4 mm according to Stafford (1905)), to less

than 2 mm in specimens available to the writer. The specimen of *U. caligorum* from England reported by Baylis and Jones (1933) were made available for comparison through the courtesy of Doctor Baylis, and a study of these specimens showed no essential differences, either in size or in other respects, between them and the specimens from the United States.

Genera inquirenda

Genus ECHINELLA Beneden and Hesse, 1863

Diagnosis.—Body elongate, cylindrical, annulated. Posterior haptor relatively large, sucker-like. Pharynx with 2 chitinous hooks; intestine (?).

Type species.—*Echinella hirundinis* Beneden and Hesse, 1863.

Genus PTERONELLA Beneden and Hesse, 1863

Diagnosis.—Body elongate, annulated when young. Anterior end with ciliated aliform membrane. Posterior haptor relatively large, sucker-like. Pharynx armed with a large number of chitinous stylets; intestine (?).

Type species.—*Pteronella molvae* Beneden and Hesse, 1863.

No representatives of these very inadequately characterized genera have been reported from North America.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

40TH ANNUAL MEETING

The 40th Annual Meeting of the Washington Academy of Sciences was held in the Assembly Hall of the Cosmos Club, January 20, 1938 with 50 members present. President CHARLES THOM called the meeting to order at 9:15 P.M.

The minutes of the 39th Annual Meeting were presented and approved. The Corresponding Secretary, NATHAN R. SMITH, submitted the following report on the membership and activities of the Academy:

Membership: During 1937, 38 were elected to resident and 1 to non-resident active membership. Of these, 28 have qualified for resident membership to date. Six were elected in recognition of their work in Chemistry; 4 in Electricity and Radio; 4 in Zoology; 3 in Geology; 3 in Bacteriology; 3 in Entomology; 3 in Medicine; 2 in Soil Science; 2 in Phytopathology; 2 in Biology; 2 in Forestry; 2 in Physics; and 1 each in Plant Physiology, Engineering and Meteorology. There were 4 resignations (1 resident and 3 non-resident), and 12 deaths. Twenty-one were dropped for non-payment of dues (12 resident and 9 non-resident). The net loss in membership was, therefore, 9.

The following deaths were reported:

CLARENCE B. MOORE, Philadelphia, Pa., 1936
F. V. COVILLE, Washington, D. C., January 9, 1937.
WM. M. BEAMAN, Washington, D. C., March 2, 1937.
WM. A. White, Washington, D. C., March 7, 1937.
ELIHU THOMSON, Lynn, Mass., March 13, 1937.
C. H. SMYTH, JR., Princeton, N. J., April 4, 1937.
WM. M. WHEELER, Cambridge, Mass., April 19, 1937.
O. P. HOOD, Washington, D. C., April 22, 1937.
PAUL V. ROUNDY, Washington, D. C., June 21, 1937.
A. B. CLAWSON, Washington, D. C., June 30, 1937.
J. N. B. HEWITT, Washington D. C., October 14, 1937.
LORD RUTHERFORD (Honorary Member), Cambridge, England, Oct. 19, 1937.

On January 1, 1938, the membership consisted of 13 honorary members, 3 patrons and 515 active members, one of which was a life member. Of the active members, 388 were classed as resident and 127 as non-resident. Since the By-Laws limit the number of active members to 400 resident and 200 non-resident, but do not include retired active members of which there are 22 resident and 6 non-resident, there were, therefore, 34 vacancies in the resident and 79 vacancies in the non-resident membership.

The Board of Managers held five meetings during the year, with an average attendance of 17.

The Recording Secretary presented the following report:

The 40th year of the Academy began with the 276th meeting and ended tonight with the 283rd meeting.

The 267th meeting was a joint meeting with the Washington Section, American Institute of Electrical Engineers; the Washington Section, Ameri-

can Society of Mechanical Engineers; the Washington Post of the Society of American Military Engineers and the Washington Society of Engineers. The meeting was held on February 18, 1937 in the Department of Commerce Auditorium with about 450 in attendance. The address was to be given by VLADIMIR KARAPETOFF, Professor of Electrical Engineering, Cornell University. On account of illness Professor KARAPETOFF was forced to cancel the engagement at the last minute. As a substitute, an address was given by GEORGE OTIS SANFORD of the Bureau of Reclamation on the *Grand Coulee and Boulder Dam Projects* illustrated with moving pictures.

The 277th meeting was a joint meeting with the Philosophical Society of Washington and the Washington Section of the Institute of Radio Engineers. The meeting was held in the Assembly Hall of the Cosmos Club on March 18, 1937 with about 250 in attendance. The address was given by ROBERT R. MCMATH, Director of the McMath-Hulbert Observatory of the University of Michigan. The subject of the address was *Solar Phenomena in Motion Pictures* and *A Motion Picture Journey to the Moon.*

The 278th meeting, a joint meeting with the Biological Society, was held on April 8, 1937 in the Auditorium of the National Museum with about 347 in attendance. The address was given by ARTHUR A. ALLEN, Professor of Ornithology, Cornell University on *American Ornithology, Past and Present.* The address was illustrated with sound moving pictures reproducing the songs of various birds.

The 279th meeting was held in the Assembly Hall of the Cosmos Club on April 29, 1937 with about 200 in attendance. An illustrated address was given by F. SIMON, Oxford University, England, on the subject, *The Production and Measurement of Extremely Low Temperatures.*

The 280th meeting was held on October 21, 1937 in the Assembly Hall of the Cosmos Club with about 50 in attendance. The address was given by STUART A. RICE, Chairman of the Central Statistical Board on the subject, *The Census of Partial Employment, Unemployment and Occupation.*

The 281st meeting was held on November 18, 1937 in the Auditorium of the National Museum with about 120 in attendance. The illustrated address of the evening was given by C. W. GILMORE, Curator, Division of Vertebrate Paleontology, National Museum. After the lecture those in attendance were taken through the exhibition halls and laboratory rooms of the division of vertebrate paleontology to view the exhibits under the leadership of the speaker.

The 282nd meeting on December 16, 1937 was held in the Assembly Hall of the Cosmos Club with about 60 in attendance. An illustrated address was given by R. R. WILLIAMS, Chemical Director, Bell Telephone Laboratories, on the subject, *The Quest for Vitamin* B_1.

The 283rd meeting of the Academy was held in the Assembly Hall of the Cosmos Club on January 20, 1938 with 60 persons present. An illustrated address was given by F. R. MOULTON, Permanent Secretary of the American Association for the Advancement of Science on the subject, *Celestial Science.*

The report of the Treasurer, H. G. AVERS, was read by HOWARD S. RAPPLEYE:

CASH RECEIPTS AND DISBURSEMENTS

RECEIPTS		
From Back Dues	$ 125.00	
From Dues for 1937	2365.00	
From Dues for 1938	15.00	
From Subscriptions for 1937	875.80	
From Subscriptions for 1938	312.70	
From Sales of Journals	124.29	
From Payments for reprints	306.50	
From Sale of halftone plate	6.10	
From Sales of Directory for 1937	38.00	
From Interest on Deposits	47.95	
From Interest on Investments	1064.50	
From Sale of Bond of Potomac El. Power Co.	999.35	
From Sale of Bond of Amer. Tel. & Tel. Co.	2199.00	
From Sale of Bond of So. Bell Tel. & Tel. Co.	1049.25	
Total receipts	$9528.44	
Cash Balance January 1, 1937	4635.63	
To be accounted for		$14,164.07
DISBURSEMENTS		
For Secretary's Office, 1936	$ 37.95	
For Secretary's Office, 1937	276.23	
For Treasurer's Office	179.11	
For Journal Printing, 1936	336.11	
For Journal Printing, 1937	2359.29	
For Journal Reprints, 1936	139.20	
For Journal Reprints, 1937	440.85	
For Illustrations, 1937	339.09	
For Meetings Committee, 1936	41.21	
For Meetings Committee, 1937	378.55	
For Printing of Directory	685.21	
For Projection lens	98.70	
For Dues of Retired members returned	45.00	
Bank Debit Memos, as follows:—		
Dues $0.35		
Subscriptions .11	.46	
Total Disbursements	$5356.96	
Cash Balance December 31, 1937	8807.11	
Total		$14,164.07

The investments listed amounted to $16,046.37.

The Auditing Committee, ARTHUR A. BAKER, WILLIAM A. DAYTON and GORDON M. KLINE reported:

"The Treasurer's records of receipts and expenditures as shown in his account books and included in his report have been examined and found correct. All vouchers have been examined and found to be correct and properly approved. The balance sheet's submitted by the bank and the securities listed in the Treasurer's report have been examined. The statement of the

assets of the Academy was found correct. No coupons not yet due were missing from any of the securities bearing coupons. The records of the Treasurer's office have been carefully and systematically kept, thus greatly facilitating the work of the auditing committee."

The Board of Editors, R. W. BROWN, E. H. TOOLE and F. D. ROSSINI submitted the following report covering the publication of Volume 27 of the Journal for the year 1937:

"Volume 27 consisted of 12 issues amounting to 548 pages, 6 pages less than Volume 26. It contained 69 original papers, 7 less than in 1936. Of these papers, 41 were by members of the Academy, and 28 were communicated; 56 came from contributors residing in or near the District of Columbia, 13 from outside sources. Five contributors of communicated papers in this or preceding volumes of the Journal were elected to membership in the Academy during the past year. Original papers were illustrated by 54 line cuts and 17 half-tones. In several instances contributors either furnished engravings or paid for those in excess of the normal number allowed by the Journal. Space in Volume 27 was distributed as follows:

	Papers	Pages	Percent of space
Anthropology	2	12.9	2
Botany	15	93.2	17
Chemistry	4	45.6	8
Entomology	9	59.5	11
Geology	7	68.3	13
Mathematics	1	4.3	1
Ornithology	3	13.0	2
Paleontology	11	46.8	9
Physics	2	32.0	6
Zoology	15	118.0	22
Obituaries	13	11.2	2
Proceedings		35.2	6
Index		8.0	1

"The total cost of printing and distributing the Journal was $3,046.83, or $5.56 per page. This is 46 cents per page higher than in 1936, a rise due to increased costs of paper, illustrations, and printing."

The tellers, L. V. JUDSON, S. F. BLAKE and J. H. ROE reported the election of the following officers: President, PAUL E. HOWE; Non-resident Vice Presidents, JAMES FRANCK and W. T. THOM, JR.; Corresponding Secretary, NATHAN R. SMITH; Recording Secretary, OSCAR S. ADAMS; Treasurer; H. G. AVERS; Board of Managers, F. G. COTTRELL and N. M. JUDD.

The Corresponding Secretary read the list of nominations for vice-presidents submitted by the affiliated societies as follows:

Philosophical Society—N. H. HECK
Anthropological Society—HENRY B. COLLINS, JR.
Biological Society—H. C. FULLER
Chemical Society—F. C. KRACEK
Entomological Society—C. F. W. MUESEBECK
National Geographic—A. WETMORE
Geological Society—R. C. WELLS
Medical Society—FRED O. COE
Historical Society—ALLEN C. CLARK

Botanical Society—W. A. DAYTON
Archaeological Society—ALES HRDLICKA
Foresters—G. F. GRAVATT
Washington Engineers—PAUL C. WHITNEY
Electrical Engineers—H. L. CURTIS
Mechanical Engineers—H. N. EATON
Helminthological Society—E. W. PRICE
Bacteriological Society—L. A. ROGERS
Military Engineers—C. H. BIRDSEYE
Radio Engineers—H. G. DORSEY

By vote of the Academy, the Recording Secretary was instuctd to cast one vote for the list as read and the vice-presidents were declared elected.

President THOM appointed Past Presidents MEINZER and TUCKERMAN to escort President-elect HOWE to the chair. President HOWE took over the gavel and addressed the Academy briefly.

Adjournment followed at 10:10 P.M.

OSCAR S. ADAMS, *Recording Secretary*

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BOTANICAL SOCIETY

278TH MEETING

The 278th regular meeting was held in the assembly hall of the Cosmos Club, January 5, 1937, President GEORGE M. DARROW presiding; attendance 110.

Program.—T. K. PAVLYCHENKO: *Root systems of certain forage crops in relation of management of agricultural soils* (lantern). Root studies were reported on three grasses: *Bromus inermis, Agropyron tenerum,* and *A. cristatum,* in relation to their efficiency in controlling weeds and binding soil. Complete root systems were carefully studied and measured. Special methods for excavating, washing and studying the roots were described and illustrated. *A. cristatum* excelled in ability to combat weeds and bind soil. *Bromus inermis* and *A. tenerum* ranked second and third respectively.

A special meeting of the Botanical Society was held in the assembly hall of the Cosmos Club, January 19, 1937; attendance 137. Governor George D. Aiken of Vermont gave an illustrated lecture on *Pioneering with Wild Flowers.*

279TH MEETING

The 279th regular meeting was held in the assembly hall of the Cosmos Club February 2, 1937, President GEORGE M. DARROW presiding; attendance 110. L. W. BOYLE and NEIL WADE STUART were elected to membership.

Program.—MERLE T. JENKINS: *Recent advances in the use of hybrid vigor in corn production.* Hybrid corn has been developed as a result of the inbreeding investigations of G. H. Shull and E. M. East which began in 1905. The publication of Shull's suggestions in 1908 and 1909 for the development of inbred lines of corn and their utilization in hybrids marked the

beginning of a new era in corn breeding. These suggestions are still the underlying procedures of the present hybrid corn program. However, there has been considerable progress in the methods and techniques connected with their application, in the isolation of better inbred lines, in the testing of these lines in hybrid combinations and in the kinds of hybrids in use. The first hybrid seed corn was sold in 1921, only 16 years ago. It is estimated that 3.5 million acres will be planted to hybrid corn in 1937.

H. L. WESTOVER: *Plant exploration in Turkey.* The speaker, accompanied by Frederick L. Wellman of the Division of Horticultural Crops and Diseases, spent seven months in Turkey in 1936, searching for new plants, particularly drouth resistant grasses and legumes, and disease resistant vegetables. Approximately 3500 lots of seed, bulbs, etc., were collected on this expedition.

280TH MEETING

The annual banquet and 280th regular meeting of the Botanical Society was held in the ball room of the Kennedy-Warren Hotel March 9, 1937; attendance 157.

Program.—HOMER L. SHANTZ gave a lecture on the vegetation of Arizona, which was illustrated with lantern slides, many of which were colored.

A special meeting was held March 23, 1937, in the auditorium of the Department of Agriculture.

The Department of Agriculture kindly presented four interesting motion picture films dealing with several phases of plant investigation, culture and exploration, entitled: *Explorations in Ceylon, Sumatra and Java; Bamboos—The giant grasses of the Orient; Persimmon harvesting and storage in China;* and *Life of plants.*

281ST MEETING

The 281st regular meeting was held in the assembly hall of the Cosmos Club April 6, 1937, President GEORGE M. DARROW presiding; attendance 53. H. H. THORNBERRY, LENA ARTZ and LOUISA AMES were elected to membership.

Program.—PAUL CONGER: *The Diatom, an economic plant.* Probably few people have thought of the diatom specifically in such terms, yet diatoms satisfy all qualifications of the definition of an economic plant. They grow so prolifically, wide spread, and abundantly in practically all waters of the earth, as to produce inestimable quantities of substance. This substance is indirectly important to man, in serving as a primary food supply of fish, oysters, and innumerable other organisms on which they feed, just as economic grasses support farm animals. In certain places, as the oyster beds of France, their propagation is even encouraged by artificial culture. More directly diatoms are useful to man in producing a material, their silica shells, which, in quantity, comprise diatomaceous earth, a substance essential to many industrial processes or products, for purposes of insulation, filtration, as a filler, an absorbent, an abrasive and many other industrial uses. The high oil content of the diatom cell has probably also contributed to the oil reserves, of great economic importance to man. Though much time may have elapsed since the life of the plant and the availability of the material produced, it is none the less economic.

Diatoms, though generally useful, may not always be beneficial to man. They may, at times, interfere with fish life, and city filtration or sanitary systems, or give unpleasant odor to drinking water. Thus in the sense that harmful insects largely make up the work of economic entomology, diatoms

may again be considered economic plants affecting adversely the economy of man.

In the broader and philosophical sense everything is economic, in that all contribute to the smooth and rhythmic functioning of a unified, balanced and orderly world. In this sense diatoms play a most significant role in the broader cycles of nature. Our sense of relative economic importance should extend beyond the more obvious and direct, to the ecological importance as well.

H. D. BARKER: *Some observations on useful and wild plants in Haiti.*

282ND MEETING

The 282nd regular meeting was held in the assembly hall of the Cosmos Club, May 4, 1937, President GEORGE M. DARROW presiding; attendance 109.

Program.—ROBERT F. GRIGGS: *Timberlines in the northern Rocky Mountains.* The demonstration previously made that the forest is invading the tundra in Alaska raises the question of the extent of the migration. Much evidence indicates that in the southwest vegetation is static. In Greenland, excavation of the Old Norse Colony indicates great deterioration of climate within the last thousand years. In the northern Rocky Mountains, many timberlines are advancing as at Kodiak. All trees are young and without dead wood or other evidence of climatic control, but all cases examined were secondary advances repossessing ground deforested by fire or grazing. Except for local retreats in some sections, alpine timberlines from Wyoming to Jasper are stable, showing therefore that the climatic improvement indicated in Alaska does not extend into the Canadian Rockies.

W. T. SWINGLE: *Plant relationships, how determined and for what use, especially in plant breeding.*

283RD MEETING

The 283rd regular meeting was held in the assembly hall of the Cosmos Club October 5, 1937, President GEORGE M. DARROW presiding; attendance 70. RUSSELL G. BROWN, MARK W. WOODS, EDGAR P. WALLS, CORNELIUS B. SHEAR and C. L. LEFEBVRE were elected to membership.

Notes and Reviews.—W. W. DIEHL brought to the attention of the meeting an interesting case of a fungus attacking the inside of a wooden apple made in Japan and sold to merchants in Winchester, Virginia, to be used as an apple-candy container.

Program.—R. KENT BEATTIE: *A new disease threatening the future of the persimmon.* The American persimmon tree is important in preventing soil erosion and in furnishing food for wild life. It supplies high grade wood for the making of gold stick heads.

Recently a serious wilt disease has been found in Tennessee southeast of Nashville. This disease kills the trees rapidly. It has proved to be due to a species of *Cephalosporium.* The fungus forms spores very abundantly under the bark when it loosens after the death of the tree and in crevices of trees killed by the disease. No remedies are known. Susceptibility and resistance in other persimmon species have not yet been determined.

W. R. CHAPLINE: *Ecology in the restoration of the western range.* Restoration of depleted ranges is of vital concern to the social and economic welfare of the western United States. The range resource and its use affecting 728 million acres, nearly two-fifths of the continental United States, presents a biological problem of first magnitude. It concerns the production of native

forage crops and their utilization in livestock and wildlife production; and management of the land and its forage cover to obtain erosion control and water delivery for irrigation agriculture, power, and municipal use.

Past use has failed to maintain the resource, resulting in serious and practically universal range and soil depletion with its related social and economic losses. Ecological research makes possible a better understanding of man's destructive forces on range lands. Likewise it aids in pointing the way to remedial measures that will stop depletion and restore and maintain the range under continued use, essential features in the formulation of policies and programs for range restoration and management.

284TH MEETING

The 284th regular meeting was held in the assembly hall of the Cosmos Club, November 2, 1937, President GEORGE M. DARROW presiding; attendance 147. EDWARD H. GRAHAM, ALTON A. LINDSEY, VERA E. MILLSAPS, L. P. MCCANN and ALBERT H. TILLSON were elected to membership.

Notes and Reviews.—CHAS. THOM gave a brief resume of the work of A. F. BLAKESLEE with colchicine used to double the number of chromosomes in several species of plants.

Program.—S. L. EMSWELLER: *Cytology and flower breeding.* An introductory discussion of the field of general cytology was presented, which included the historical background which has led up to the modern conception. There were also presented some generalizations as to chromosome pairing in normal balanced species as compared to species hybrids. The manner in which cytology can aid in explaining problems of sterility and failure to secure crosses was discussed. It was pointed out that doubling the chromosome number of a hybrid in which there is complete failure of pairing will ordinarily give rise to an amphi-diploid. Such a new condition will not result in crossovers and recombinations between the two unrelated genoms.

J. W. MCKAY: *Cytology and nut breeding.* The results of breeding work with plants are determined by the number and behavior of chromosomes that are distributed to the germ cells. In many genera, such as *Rubus* and *Triticum*, there is a series of chromosome numbers that are multiples of a common base number, and the products of species hybridization are dependent upon the behavior and distribution of the chromosomes in the hybrid individuals.

Among nut-producing plants the genus *Hicoria* offers the only case of a polyploid series, one group of species exhibiting 32 and another group 64 somatic chromosomes. The following somatic chromosome numbers are found in nut species: walnuts, 32; hazelnuts and filberts, 28; chestnuts, 24; almonds, 16.

The embryo of the seed is the edible portion of the fruit in all of the nut species. The embryo develops only after a viable zygote has been produced by fertilization of the egg by a sperm nucleus. Thus, in order that nut trees be productive, it is necessary that the reproductive processes in the flowers function in a normal manner. A study of the chromosomes in the cells which produce the pollen and eggs may disclose irregularities that help to explain why many varieties and species are unproductive.

A. E. CLARKE: *Cytology and potato and onion breeding.* A serious problem facing the potato breeder is the difficulty in obtaining seeds. *Solanum tuberosum* is either tetraploid or octoploid in origin and, during meiosis, there is considerable secondary association between different pairs of chromosomes, resulting in chromosomal irregularities and pollen sterility. Environmental

factors, such as length of day, temperature and humidity, are important because they influence flower production and the abscission of buds before pollination. Cytological studies are being carried on to show whether these environmental influences also affect pollen fertility. By providing optimum conditions it may be possible to secure some viable pollen from varieties ordinarily sterile. Wild species form a polyploid series. The cytologist can assist in analyzing and interpreting the results obtained from interspecific hybridization.

Cytological examination of a sterile onion, which is also mildew resistant, has so far failed to disclose any chromosomal irregularities. Commercial varieties of garlic never produce seed. Further cytological studies may solve these sterility problems.

H. DERMEN: *Cytology and fruit breeding.* Methods have been devised to facilitate quick determination of the cytological constitution of plants dealt with at the United States Horticultural Station at Beltsville, Maryland. Recently induction of polyploidy by artificial means has indicated interesting possibilities of creating new forms, some of which may be of great value commercially. Some factors found to influence polyploidy include temperature changes, genetic factors, narcotics and chemicals, diseases or insects, osmotic changes, treatment with X-ray or ultra-violet light, chromosomal incompatibility in species hybrids, mechanical disturbance by centrifuging, physiological disturbance by breaking the rest period. Some possible advantages of polyploids are large size of the plant as a whole, increased vigor, wider distribution, resistance to disease and to cold. Some annuals are changed to perennials, and sterile hybrids may be changed to fertile ones.

285TH MEETING

The 285th regular meeting was held in the assembly hall of the Cosmos Club, December 7, 1937, Vice-president G. F. GRAVATT presiding; attendance 60. EARNEST A. WALKER was elected to membership.

Program.—ERSTON V. MILLER: *Plant pigments with special reference to citrus fruits.* The pigments responsible for the great array of color in the higher plants may be grouped as follows: (1) the water-soluble and (2) the ether-soluble or plastic pigments. In the first group are the anthocyanins (red, blue and purple) and the flavone and flavonol pigments (yellow). In the second group are the chlorophylls (green) and the carotenoids (yellow). Though it is customary to think of the carotenoids of green leaves as consisting of carotene and xanthophyll, it is now known that there might be two or three isomeric carotenes and as many as twelve xanthophylls present, and the whole list of carotenoids that have been isolated from different plants is so great now that only a specialist can keep this list up to date.

Carotenoid pigments have been found in the rinds of mature green limes, lemons and grapefruit, but these pigments diminish in quantity as the fruit degreens. This is true whether the fruit is degreened with ethylene or is permitted to degreen on the tree. Oranges, on the other hand, show an increase in carotenoid content of the rind as they attain full color on the tree.

37TH ANNUAL MEETING

The 37th annual meeting was held immediately following adjournment of the 285th regular meeting, Vice-president G. F. GRAVATT presiding; attendance 44.

M. B. WAITE, H. L. WESTOVER and WM. A. DAYTON made brief remarks on the lives and works of FREDERICK V. COVILLE, HARRY N. VINALL and ARTHUR B. CLAWSON, respectively.

O. F. COOK, G. G. HEDGCOCK and S. L. JODIDI were elected to honorary membership.

The following officers were elected for 1938: President, G. F. GRAVATT; Vice-President, H. H. MCKINNEY; Recording Secretary, ALICE M. ANDERSEN; Corresponding Secretary, ERSTON V. MILLER; Treasurer, NELLIE W. NANCE.[1]

Nominated for Vice-President Washington Academy of Sciences, WM. A. DAYTON.

H. H. MCKINNEY, *Recording Secretary.*

[1] Resigned. KENNETH B. RAPER appointed by the Executive Committee.